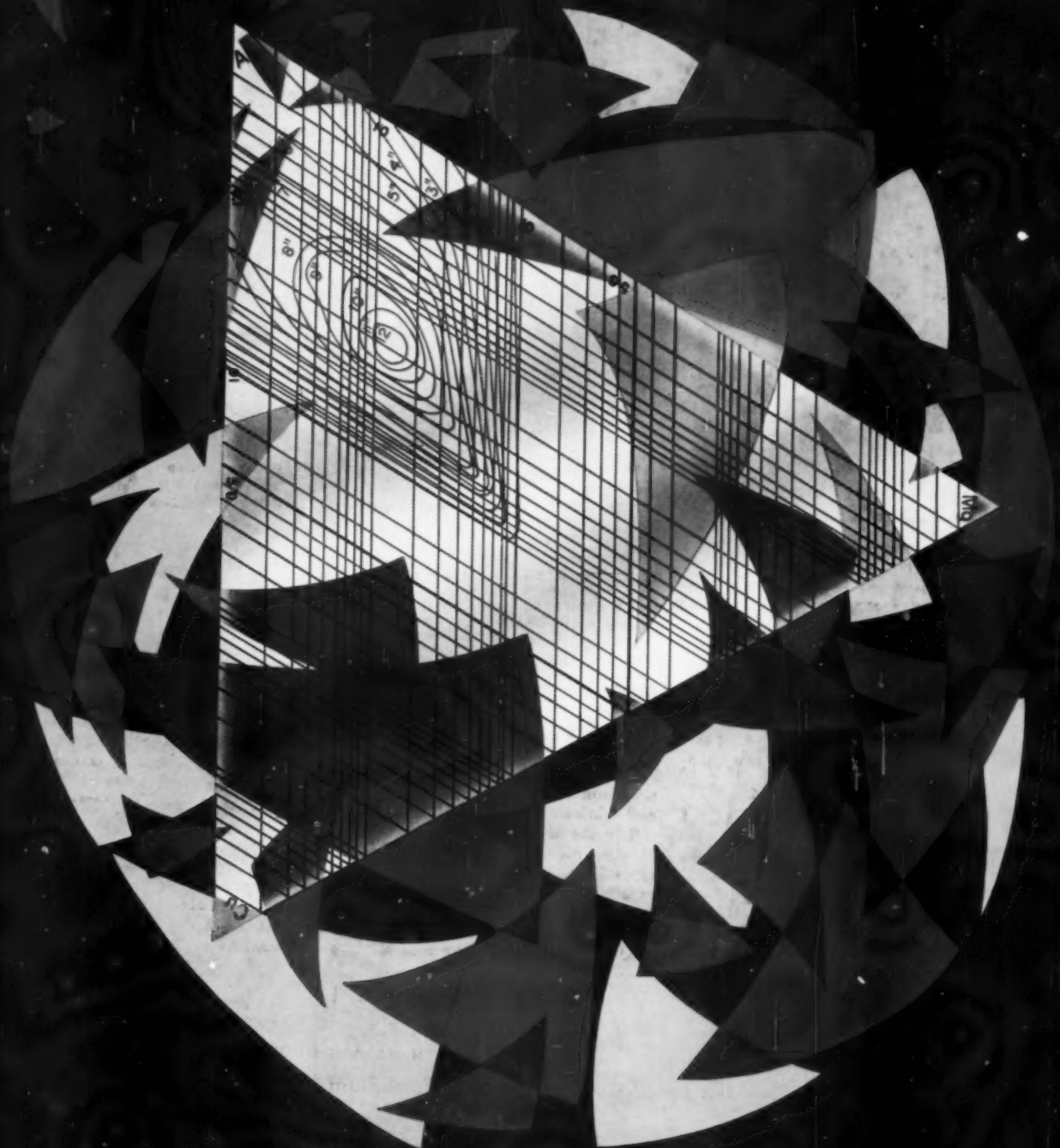
Metal Progress



Cost cutting ideas in **TITANIUM**

TITANIUM BELONGS IN THIS CORROSIVE PROCESSING PICTURE

Write for *Technical Data Sheets on "Cost Cutting Ideas in Titanium for the Pulp and Paper Industry"—on your business letterhead, please. Address: Commercial Market Development, Dept. C, Mallory-Sharon Metals Corporation, Niles, Ohio.*

Here's why: Today, titanium is competitive pricewise with nickel base alloys when density is taken into account. Its service life is often many times that of nickel base alloys or stainless steel. And titanium is about the same to weld and fabricate.

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Integrated producer of Titanium • Zirconium • Special Metals

Metal Progress

July 1959..... Volume 76, No. 1

For an explanation of the tri-axial diagram on the cover, see the Correspondence Department, p. 116. Don Davis of Hayes Aircraft Ordnance Operation is responsible for the colorful background.

Progress in Forging

Forging and the Space Age, by J. H. Jackson and H. B. Goodwin 65

As one of the mainstays of American production, the forging industry has progressed with the times since drop forging was introduced in 1846. Today, the industry is faced with new challenges from changing technological trends.

Hydrogen in Heavy Forgings, by J. E. Steiner 72

Hydrogen causes flakes in heavy forgings and adversely affects ductility; consequently, much effort has gone toward hydrogen reduction. Investigation proved that lengthy heat treatments are not reliable, but hydrogen is reduced somewhat by careful melting. Finally, vacuum casting techniques solved the problem. (Q23p; ST, *H*, 9-70)

Forging With King-Size Presses, by A. E. Favre 76

Alcoa's large forging presses, which include a 35,000 and a 50,000-ton model, are used to make precision forgings for aircraft and missiles. Though first cost is higher, savings in machining more than compensate for this. (F22, W22p; A1)

Engineering Articles

Mechanical Properties of A 356 Aluminum Casting Alloy, by G. N. Reinemann and L. E. Marsh 80

Since tensile strength and elongation depend so much on freezing rate, the foundry engineer should be given a full stress analysis of a complex casting so he can properly place gates, risers and chills. (G27a, E25; A1-b)

Welding Unusual Metals, by D. W. Grobecker 87

While highly reactive metals require unusual equipment and care to prevent weld contamination, the principles of the operation are but extensions of ideas widely used to make sound joints in thin sheets of conventional metals. (K-general; U, Zr)

Early Radiophotographs, by Clarence T. Patterson 91

Early in 1915 the radioactivity of uranium was used to mark the position of its carbides in ferro-uranium. Intimate details of the microstructure could not be determined because these contact prints could not be magnified very highly; the "grain" of the photographic emulsion was too coarse. (A2, M23q; Fe, U, AD-n)

Measuring Decarburization by Microhardness, by H. Czyzewski and H. H. Honegger 93

Modified method gives results that correspond more closely with metallographic measurements. (J4a, Q29q, 1-54)

Corrosion Resistance of Type 347 Stainless After "Sensitizing" Heat Treatments, by Hilmer F. Ebling and Merrill A. Scheil 94

Corrosion rates in boiling HNO_3 after a systematic series of long heatings between 700 and 1500° F. can be plotted in TTS (time-temperature-sensitization) diagrams so engineers can avoid fabrication practices which would produce unexpected damage from corrosive liquids. (R11, R2h; SS)

Descaling Wire Rods by Shot-Blast, by K. J. Sorace 98

A continuous line for drawing wire at 300 ft. per min. depends on a shot-blast method for descaling. Costs are comparable to conventional methods, and the pollution problem (from acid pickling baths) is avoided. (L10c, F28, 1-61; ST)

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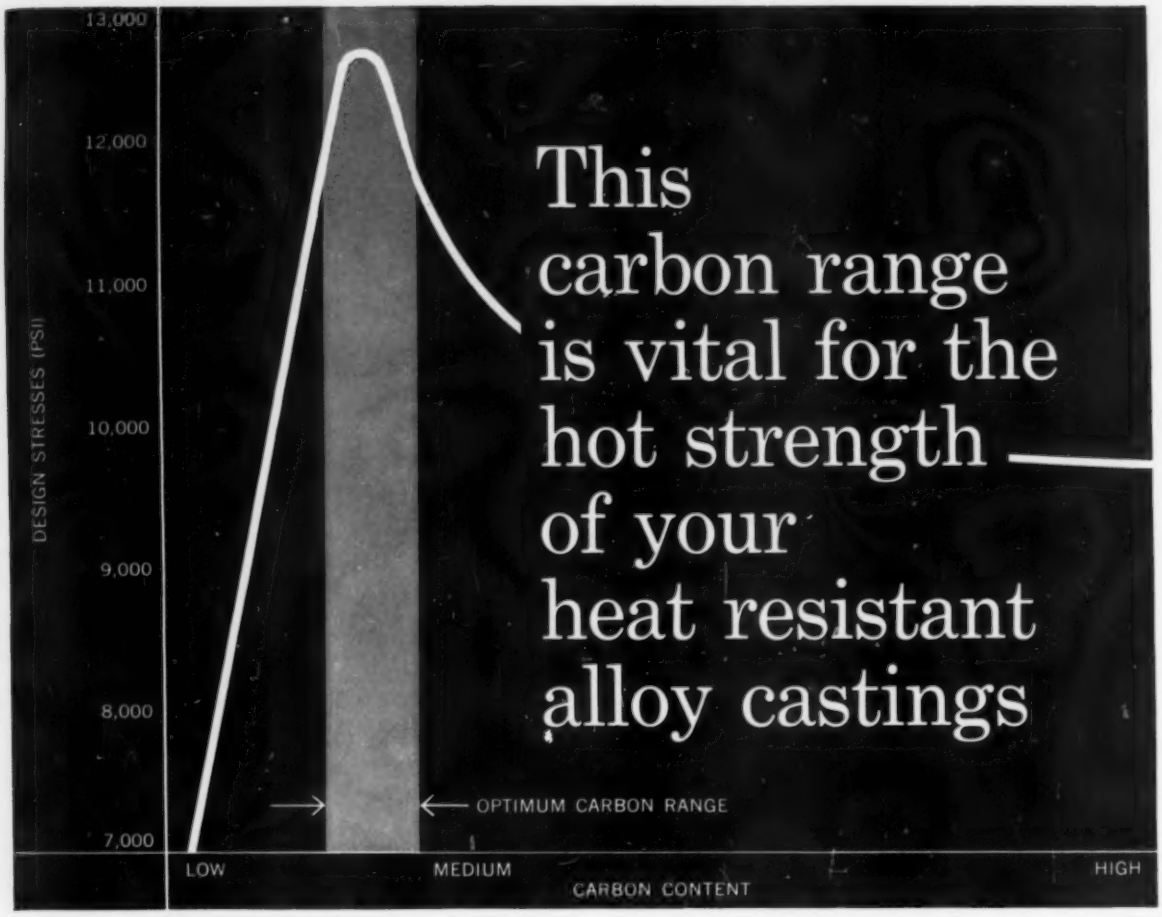
**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*



Every foundry heat is analyzed to insure specified alloy composition

This graph illustrates the effect of carbon content on the hot strength of a heat resistant alloy. It outlines an optimum carbon range. The graph shows how a carbon content outside the optimum range would seriously lower the hot strength decreasing the service life of the casting. The optimum carbon range is 0.10 percent.

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American Brake Shoe Company

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Metal Progress

Sulphur Printing . . . A new Evaluation, by S. Ramachandran and W. G. Renshaw 101

Normally quite accurate in outlining sulphide distribution in steels, sulphur prints can be adversely affected by tiny electrical currents generated between inclusion and base metal. The misleading indications which occur are explained by corrosion theory. (M23, 9-69; ST)

The Windscale Atomic Piles, by Tom Bishop 105

Ten years ago the British Government built two plutonium-producing piles at Windscale, similar to the American piles at Hanford except the coolant was air rather than river water. Both of these piles were shut down about a year ago because the graphite moderator was dangerously overheated by "Wigner energy". It is unlikely that the British power-producing piles which use carbon dioxide as a coolant and heat-transfer medium will be similarly endangered. (W11p)

Book Review

A Comprehensive Appraisal of Molybdenum, Reviewed by J. Gordon Parr 110

"The Metal Molybdenum", edited by Julius J. Harwood from an A.S.M. symposium supplemented by many specially written chapters, communicated an "infectious enthusiasm" to the reviewer.

Short Runs

Vacuum Furnace for Continuous Strip 111

Despite a slight advantage in first cost of conventional bright annealing equipment, operating savings provided by continuous vacuum equipment are such that actual cost can be halved.

Improved Chromium Plate 113

New "duplex" deposit gives thicker chromium and better protection against pinhole rusting and blistering so prevalent on automobile bumpers and other parts.

Brazing by Exothermic Reaction 114

Particularly useful for making honeycomb panels of stainless steel.

Bonded Carbides for Corrosion Resistance 114

High-Temperature Crucible 114

Data Sheet

Time-Temperature-Sensitization Diagrams for Type 347 Stainless Steel, by Hilmer F. Ebling and Merrill A. Scheil 96-B

Digest of the Month

Metal Powders for Missile Fuels 134

A number of metals in powder form, such as boron, aluminum, magesium and zirconium, fill the requirements for flammability and dispersability necessary in the new fuels.

Correspondence

Crack Sensitivity of Aluminum Alloys, by James K. Dawson 116

Ship Plate Steel, by Charles L. Staugaitis 118

Anodizing and Coloring Aluminum, by F. C. Porter 120

Electrolytic Cactus, by Takao Kawakita 120

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Metals Engineering Digest

Silver-Indium-Cadmium Alloys for PWR Control Rods 140

Full-size rods have been readily fabricated by melting, forging, extrusion and machining.

Safe Handling of Beryllium 142

Stress-Corrosion Cracking 148

Results of a four-year research stimulated by failure of alloy tubing in gas wells.

Creep-Rupture Acceptance Testing 152

A combination specimen provides both a smooth and a notched test section.

Oxidizing Test for Revealing Austenitic Grain 156

Advantages are simplicity and reliability.

Thin-*n*-Type Layers of Germanium 157

Metal Progress is published monthly by the American Society for Metals. Publication office Mt. Morris, Ill. Editorial and general offices 7301 Euclid Ave., Cleveland 3, Ohio. Entered as second class matter at the Post Office in Mt. Morris, Ill. Vol. 76, No. 1, July 1959. Copyrighted 1959 by the American Society for Metals.

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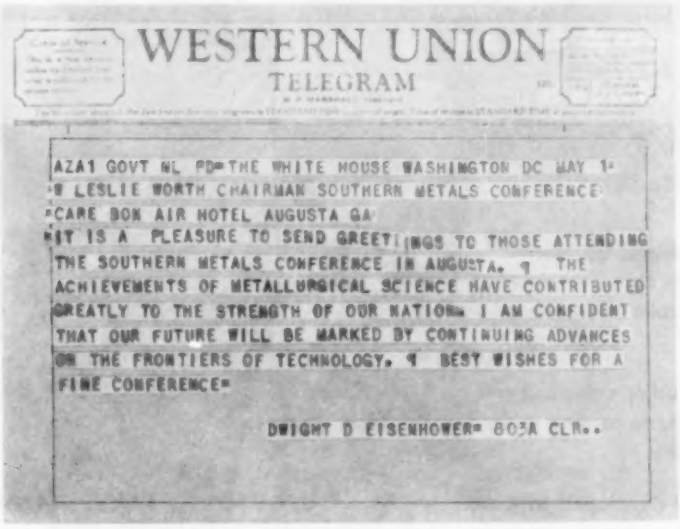
Press Breaks...

THE EDITOR attended the Southern Metals Conference during the first week of May in Augusta, Ga. The success of the conference came as no surprise because a great deal of planning and hard work had been done by the enthusiastic members of the Savannah River Chapter. Invitations of "y'all come" were extended far and wide and the very efficient conference chairman, W. Leslie Worth, invited President Eisenhower (after all, he does spend considerable time in Augusta) to attend the meeting if he could see his way clear to do so. Although the President was unable to attend, he did send his best wishes for a successful conference to Les in the following telegram:



WESTERN UNION
TELEGRAM

AZA1 GOVT NL PD=THE WHITE HOUSE WASHINGTON DC MAY 1=
W LESLIE WORTH CHAIRMAN SOUTHERN METALS CONFERENCE=
CARE BON AIR HOTEL AUGUSTA GA=
IT IS A PLEASURE TO SEND GREETINGS TO THOSE ATTENDING THE SOUTHERN METALS CONFERENCE IN AUGUSTA. ¶ THE ACHIEVEMENTS OF METALLURGICAL SCIENCE HAVE CONTRIBUTED GREATLY TO THE STRENGTH OF OUR NATION. I AM CONFIDENT THAT OUR FUTURE WILL BE MARKED BY CONTINUING ADVANCES ON THE FRONTIERS OF TECHNOLOGY. ¶ BEST WISHES FOR A FINE CONFERENCE=

DWIGHT D EISENHOWER= 803A CLR..

The Southern Metals Conference, sponsored annually by one of A.S.M.'s chapters in the Southeast, is dedicated to promoting a better understanding of the effects of metallurgy and metal working on the scientific and industrial life of the region. The theme of this year's conference was "Metallurgical Frontiers", and technical highlights of the program will be reported in *Metal Progress*.

Invariably, it seems that editors must travel, but it's necessary to get around these days to keep abreast of technological developments. After all, we are sure you share our viewpoint that an editor who doesn't know more about a subject than he writes really isn't a very good editor. For example, Assistant Editor Carl Weymueller spent the week before Decoration Day in the Chicago area exploring subjects such as atmosphere for heat treating, vacuum degassing, refractory metals, and heat treating fuel cases for the Minuteman.

And we should mention that Editor-in-Chief Thum and Mrs. Thum shoved off for Europe on the S.S. Independence the last week in May for a two-month trip, which the Editor-in-Chief insists is a vacation. We have our doubts, judging from some of the papers he took along. Perhaps by next month we will have some interesting experiences to relay to you from that part of the world.

THE EDITORS

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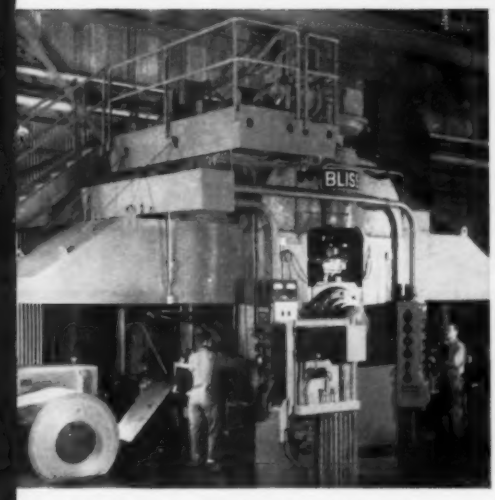

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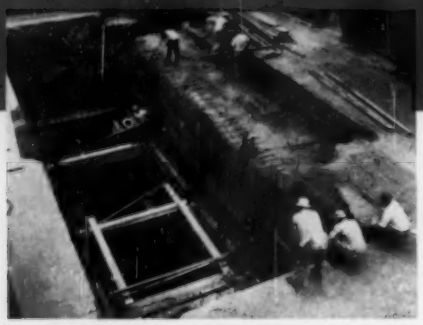
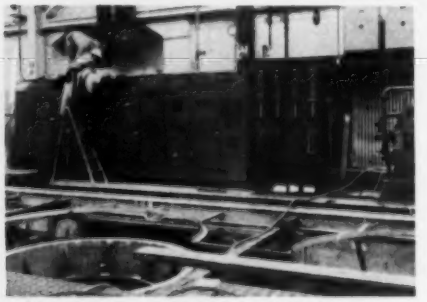
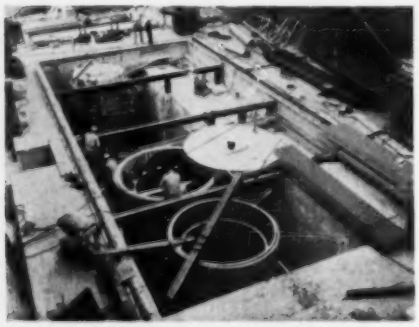


Subsurface draw furnace, oil quench, and atmosphere quench tanks were later installed in this huge pit.



Control Panels provide exacting control to eliminate human error.



Huge capacity oil quench tank (nearest camera) requires 6000 gallons special quench oil.

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The gantry furnace is rated at 400 kw and maintains close tolerance temperatures up to 2000°F. while the draw furnace is rated at 200 kw with a maximum temperature of 1350°F. Pneumatically operated sleeves make it possible to join quench tanks to the gantry furnace so that heated parts can be lowered into either tank without being exposed to air.

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- Installation includes gantry furnace, draw furnace, oil quench tank, atmosphere quench tank, and loading bay.
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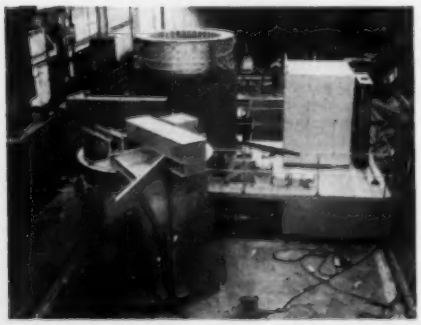
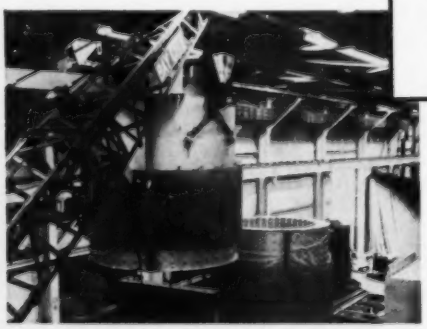
- Gantry furnace temperature range to 2000°F.
- Rated at 400 kw divided into four zones of control.
- Pit type draw furnace temperature range to 1350°F., rated at 200 kw.





Final Stages. Gantry furnace installed in two sections clears overhead beams with 2 inches to spare.

PHOTOS COURTESY DOUGLAS AIRCRAFT COMPANY

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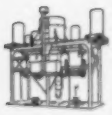

Whether you need a missile "roaster" or a tiny "toaster" (for heating tensile test samples) – *Pacific Scientific* can furnish the ONE best furnace for the job.

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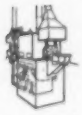

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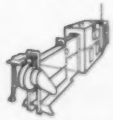

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☐ Please send me information on custom designed furnaces.

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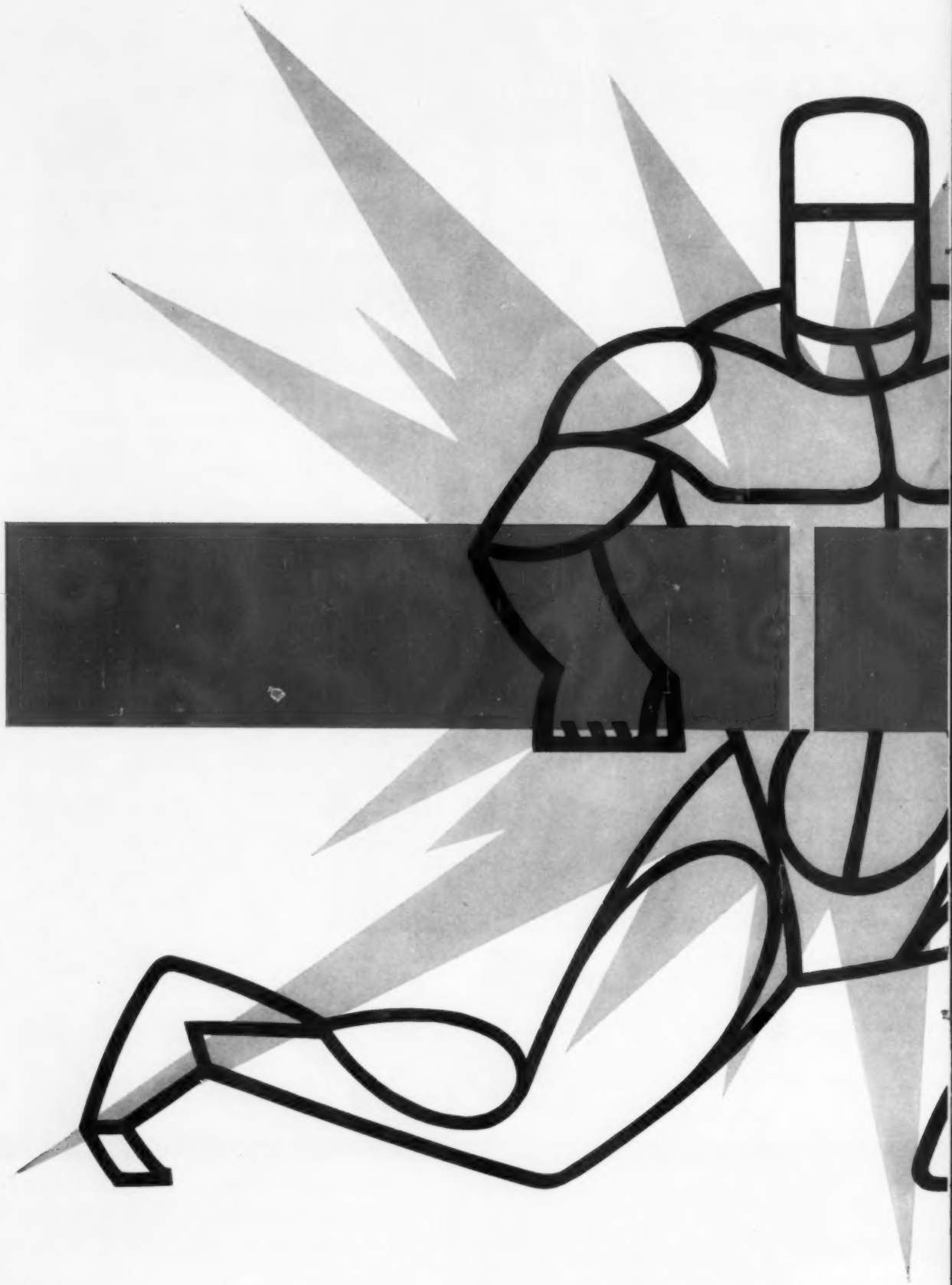

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COMBINES SUPERB WELDABILITY WITH EXTRA STRENGTH

N-A-XTRA

BEST LOW-ALLOY EXTRA-STRENGTH STEEL YOU CAN BUY

When only the strongest steels will do, specify N-A-XTRA HIGH-STRENGTH. This low-alloy heat-treated steel is now available in minimum yield strengths ranging from 80,000-110,000 psi.

Along with this great strength, N-A-XTRA is readily formed and fabricated. It can be welded by any process. The most drastic welding tests on N-A-XTRA have shown no underbead cracking, even when plate temperatures are as low as —60°F.

Because N-A-XTRA is nearly three times stronger than mild carbon steels, it gives designers an opportunity to eliminate useless dead weight from finished products and realize substantial savings. Let us show you how N-A-XTRA HIGH-STRENGTH steel can do a job for you. Write Great Lakes Steel Corporation, Detroit 29, Michigan, Dept. E-7

GREAT LAKES STEEL

A DIVISION OF NATIONAL STEEL CORPORATION

Beat the Heat Barrier With Handy & Harman High Temperature Brazing Alloys!

Some of the problems of elevated temperature joint strength and oxidation resistance in heat-resistant alloys are being solved today by a relatively new group of Handy & Harman high temperature brazing alloys. These alloys embody certain unique characteristics, all of which are requisite for high temperature brazing:

- They have good strength and oxidation resistance at recommended temperatures.
- They are ductile, with the ability to withstand vibration and stress at elevated temperatures.
- These Handy & Harman alloys provide minimum solution and penetration of the metals being joined; this is a particular advantage when joining thin sections.
- These alloys effectively join stainless steels, low alloy steels, nickel-base alloys, cobalt-base alloys and other high temperature metals including refractory types.

The list of successful applications includes jet engine parts, heat exchangers, rocket motors, clad metals, honeycomb structures, turbine blades and many others. The following are brief descriptions of these Handy & Harman alloys:

LITHOBRAZE 925 For short time operation to 900° F, continuous at 500° F. Very ductile, virtually no solution of base metal. Good salt-spray corrosion resistance.

HI-TEMP 30 For continuous service 900° F-1000° F. Fairly ductile, moderate general solution of base metal.

PREMABRAZE 128 Continuous service up to 1500° F. Ductile, moderate solution of the base metal. Tensile strength at 1600° F in 304 stainless steel is 20,000 psi (short time test).

PREMABRAZE 130 Same properties as PREMABRAZE 128, but freer flowing and lower brazing temperature.

PREMABRAZE 101 Continuous operation in 1800° F-2000° F range (based upon limited oxidation tests). Ductile, moderate solution and penetration of the base metal.

Alloy	Nominal Composition	mp° F	fp° F
LITHOBRAZE 925	92.5 Ag 7.3 Cu .2 Li	1435	1635
HI-TEMP 30	70 Mn 30 Ni	1885	1920
PREMABRAZE 128	72 Au 22 Ni 6 Cr	1785	1900
PREMABRAZE 130	82 Au 18 Ni	1740	1740
PREMABRAZE 101	54 Pd 36 Ni 10 Cr	2250	2300

Data sheets and complete details on each of the above Handy & Harman alloys are available upon request to Handy & Harman, 82 Fulton Street, New York 38, N. Y.

Your NO. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

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"We've cut stainless costs with ferromanganese-silicon"

Ferromanganese-silicon allows savings of as much as $8 per ton, depending upon practice, in the production of high-manganese stainless steels. It also reduces manganese costs for the chromium-nickel grades of stainless.

The alloy is both an efficient slag reducing agent and the lowest-priced source of low-carbon manganese currently available. For details on cost reductions in your practice, contact your UNION CARBIDE METALS representative.

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

Ferromanganese-silicon gives lower costs, rapid solubility, and high manganese recoveries.

UNION CARBIDE METALS

Electromet *Brand Ferroalloys and other Metallurgical Products*

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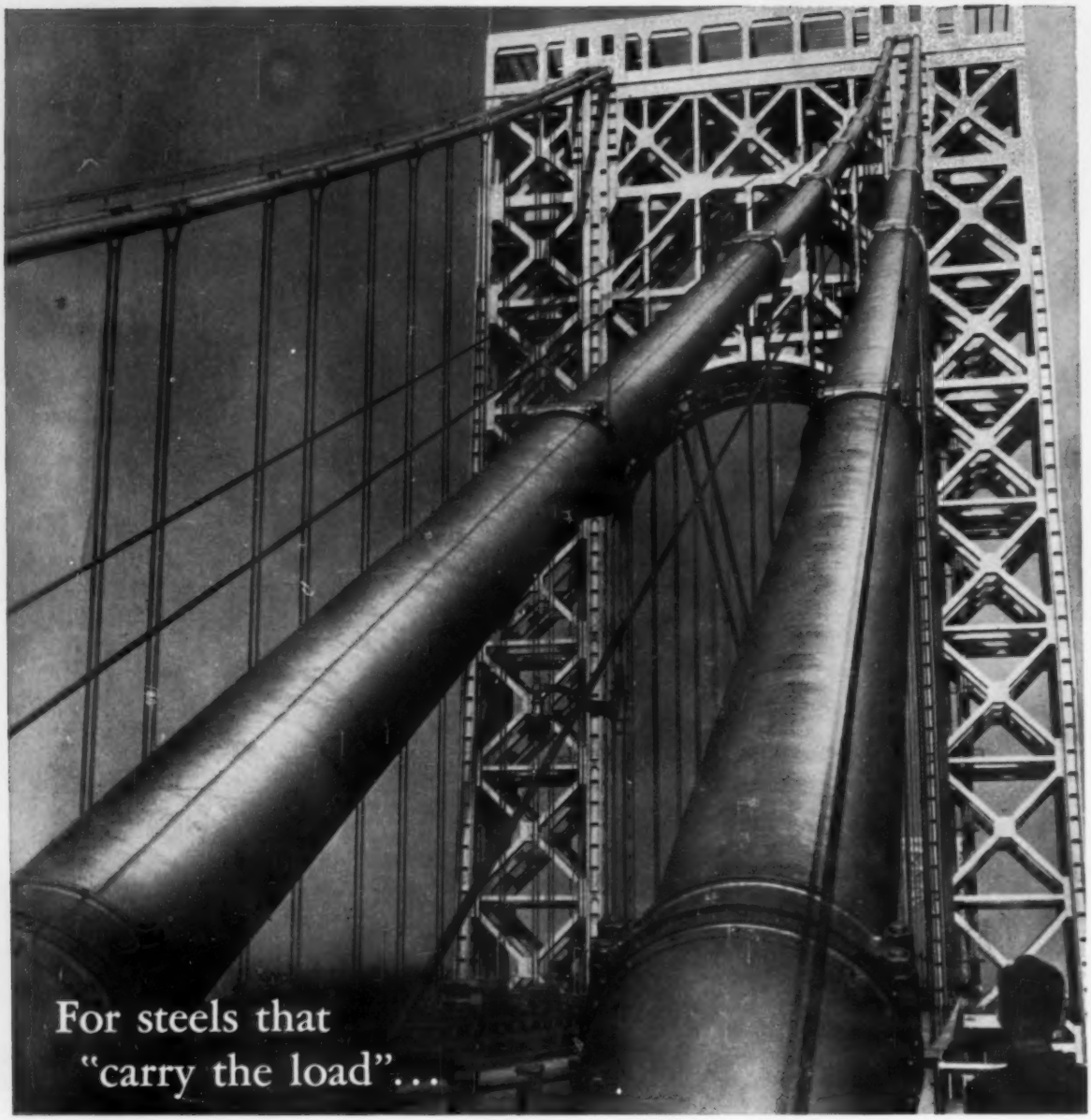

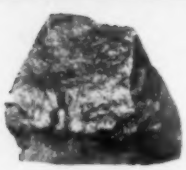

. . . Vancoram Silicomanganese! It makes structural steels tough and strong. In addition to its important alloying properties, Vancoram Silicomanganese acts as a furnace block, desulphurizer and deoxidizer, all in one. Vancoram Silicomanganese comes in every grade you need:

	MANGANESE	SILICON
Max. 1.50% Carbon Grade	65/68%	18/20%
Max. 2.00% Carbon Grade	65/68%	15/17.5%
Max. 3.00% Carbon Grade	65/68%	12/14.5%

Also available, for foundry use, are convenient, square-shaped briquettes containing 2 lb. manganese, ½ lb. silicon. Call your nearest VCA District Office or write for information and recommendations. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N. Y. • Chicago • Cleveland • Detroit • Pittsburgh

Producers of alloys, metals and chemicals

VANADIUM CORPORATION OF AMERICA

SCIENTIFIC INSTRUMENTS FOR RESEARCH AND DEVELOPMENT

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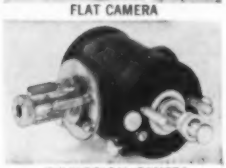

CYLINDRICAL CAMERA

GUINIER CAMERA

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STEREO-MICROCAMERA

NOW FOR AS LITTLE AS $4,000!

Complete RCA X-Ray Diffraction Equipment for all Types of Film Studies

Think of it—a complete x-ray diffraction facility for film studies can be yours now for less than $4,000.00. A typical installation could include: a Crystalloflex II X-Ray Diffraction Generator complete with two powder cameras, a flat camera, and a stereo-microcamera, a copper target x-ray tube and camera carriers. Other combinations, with prices varying according to the selection, could include both one and two radian cylindrical cameras, flat cameras and the very versatile 70mm. film with one radian cylindrical camera which can be used for powder diffraction, symmetrical back reflection work and rotating crystal layer line diagrams. A wide variety of additional cameras, x-ray tubes with other targets, and attachments for special specimen handling are also available.

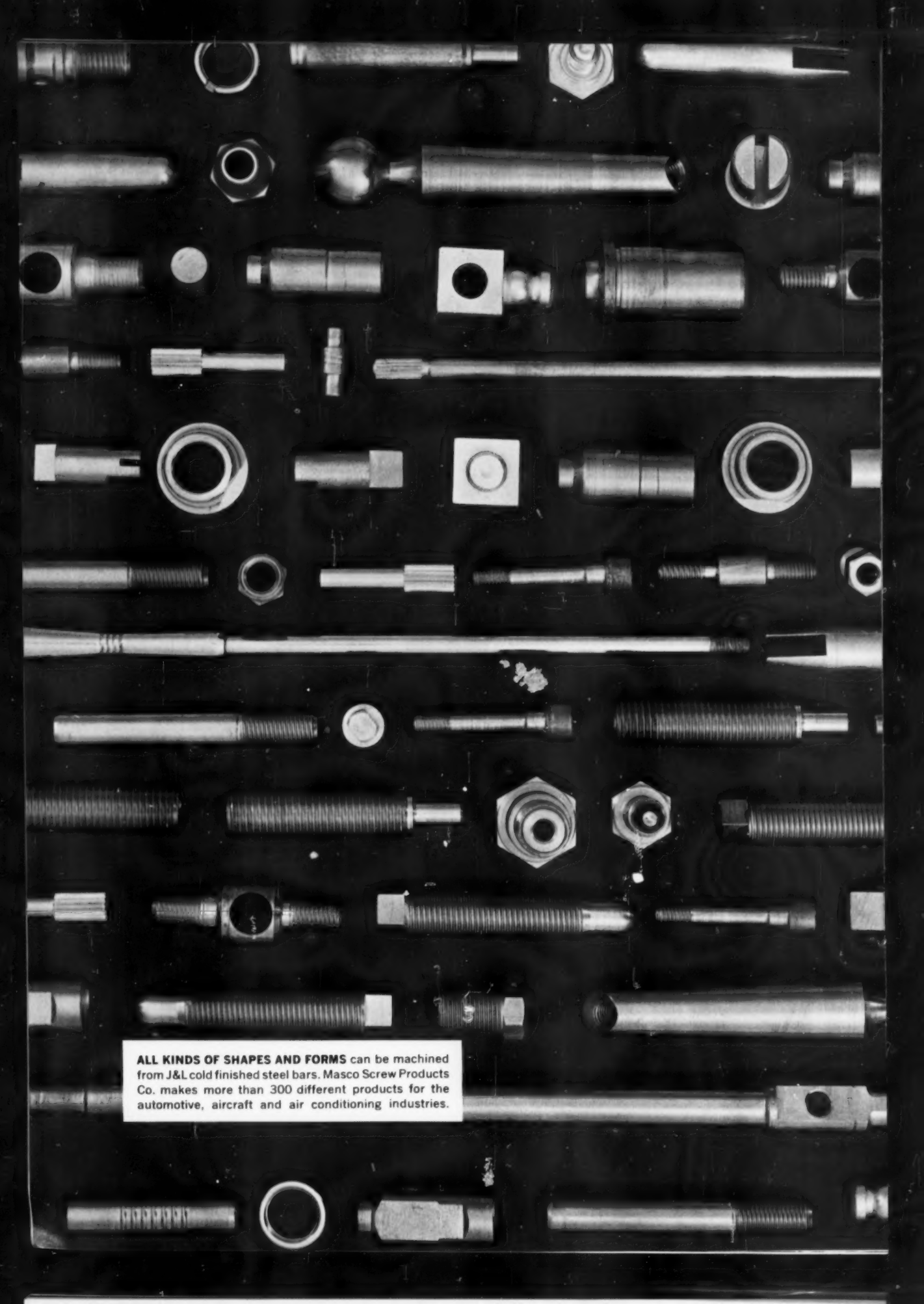
Cameras used with the Crystalloflex II can be operated simultaneously at four x-ray ports, each of which is equipped with an individually timed shutter. Rating of this compact table model is 25 to 60 KV in 5 KV steps. Tube current control is continuous from 0 to 40ma. Overall size of the unit is 24″ wide x 32″ high x 22″ deep. The Crystalloflex II can also be tilted so that the tube may be operated horizontally. All these features make this generator an excellent tool for chemists, metallurgists, physicists and biologists whose research projects usually entail a high volume and wide variety of film work.

RCA also offers the Crystalloflex IV console model generator, and the world's most complete line of attachments and accessories for x-ray diffraction and spectroscopy including an exceptionally versatile group of cameras, pole figure goniometer, single crystal layer line and microfluorescence attachments.

Contract services on RCA X-Ray diffraction equipment and electron microscopes are available through eleven regional offices of the RCA Service Company.

For more information about this advanced equipment or a quotation on your requirements, write: Radio Corporation of America, Dept. W-72, Building 15-1, Camden, N.J.

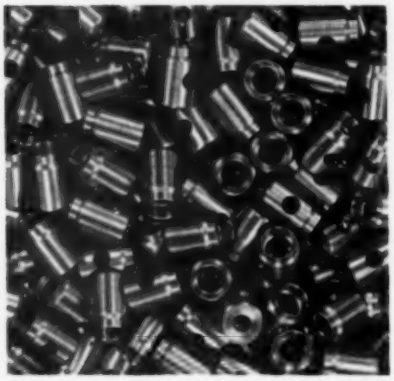
RADIO CORPORATION of AMERICA
CAMDEN 2, N. J.



ALL KINDS OF SHAPES AND FORMS can be machined from J&L cold finished steel bars. Masco Screw Products Co. makes more than 300 different products for the automotive, aircraft and air conditioning industries.

Detroit's Masco Screw Products Company uses round, square and hexagonal J&L leaded steel bars in sizes from ⅜" to 1⅛"

More than 96 automatic screw machines are in almost constant operation



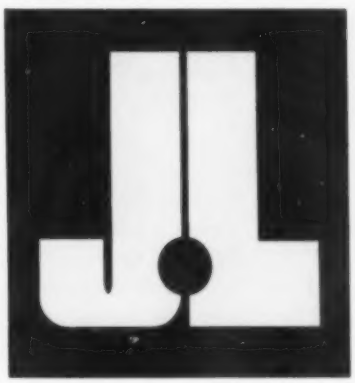
Production runs vary from less than 10,000 to more than 2,500,000 pieces

Even complex machining operations have fewer work stoppages with free machining J&L leaded steel

Parts are often so smooth after routine machining that no further finishing is necessary

Rigid Masco inspection procedures assure products of dependable quality

Masco regularly handles specifications calling for dichromate, chromium, and other protective coatings



"J&L leaded steel bars machine at maximum practicable speeds for screw machines"

. . . reports Masco Screw Products Company

"While we're seldom able to run our automatic screw machines at their maximum rated speeds, we've found that J&L leaded steel bars permit the fastest machining speeds practicable," says Alex Wood, plant engineer of Masco Screw Products Company, Detroit's largest independent manufacturer of screw machine products.

"The free machining properties of this J&L cold finished steel permit high speed production. The short length chips minimize tool edge build-up. Tool wear is reduced. And, frequently, fewer finishing operations are needed.

"This is a good steel for screw machine products."

Jones & Laughlin Steel Corporation

PITTSBURGH, PENNSYLVANIA

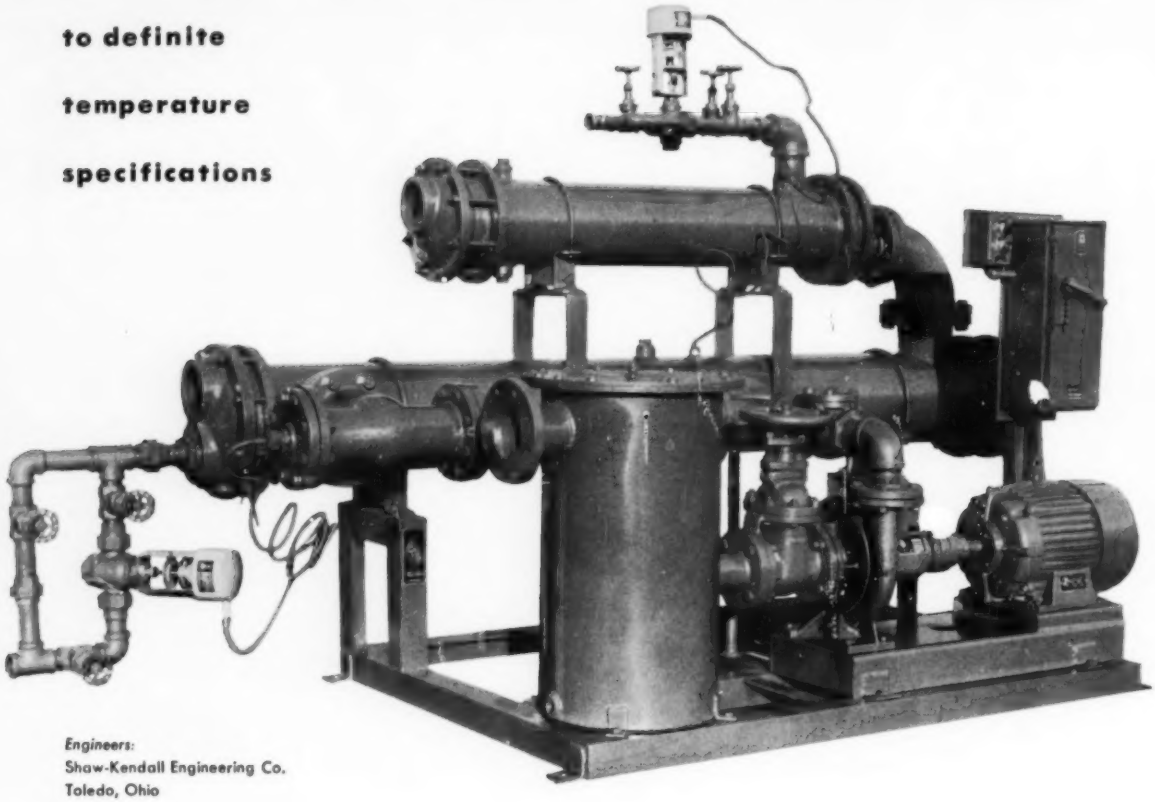
Where cold rolled steels originated in 1859

BOTH *Heats* AND *Cools* QUENCH OIL

to definite

temperature

specifications



Engineers:
Shaw-Kendall Engineering Co.
Toledo, Ohio

At the Chevrolet Motor Division of General Motors Corporation, Toledo, Ohio, this B&G Self-contained Quench Oil unit performs a double duty in controlling quench oil temperatures.

On the cooling side, it is required to remove 368,000 BTU/hr. from the oil. At a flow rate of 250 GPM, the oil enters the cooling unit at 140°F and leaves at 120°F. Cooling water enters at 85°F and leaves at 95°F and is circulated at the rate of 74 GPM.

When used as a heater, 1500 gallons of quench oil flowing at 250 GPM is heated within two hours from 60°F to 110°F. The heating medium is steam at 10 psig and is passed through the shell of the heater.

Controlled quenching temperatures is the certain way to maintain uniform quality in heat-treated metals and to avoid excessive sub-standard rejects. Whether your heat treating volume is large or small, B&G Self-Contained Oil Coolers can be engineered to your requirements... or, components can be furnished for assembly on the job. The services of the B&G engineering staff are always available.

B&G Quench Tanks
Properly designed to induce maximum turbulence in the quench oil, B&G Quench Tanks are available in standard models or can be built to meet any specific quenching requirement.

Send for this combined Catalog and Simplified Selection Manual for B&G Self-Contained Quench Oil Coolers.

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Hydro-Flo* **OIL QUENCHING SYSTEMS**

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Any trichlorethylene degreasing operation which has not been studied recently by an experienced degreasing engineer is a logical candidate for this 15% saving—*or even more.*

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They would be most pleased to study your operation.
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DETREX CHEMICAL INDUSTRIES, INC.
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Getting down to the brass tacks of **INDUCTION** heating,

THER-MONIC is the only induction heater that protects your investment!
. . . because it can be readily upgraded to higher output capacities to meet increased production requirements.
. . . and can also be readily coupled to an identical unit to double the output.

THER-MONIC is the only induction heater
. . . with a totally enclosed air-conditioned cabinet and a built-in heat exchanger that insures maximum efficiency.

THER-MONIC is the only induction heater
. . . with a variable-ratio output transformer, permitting the use of the widest range of work coils.

THER-MONIC is the only induction heater
. . . providing for 6000 KVA in tank circuit for efficient heating of non-magnetic metals.

THER-MONIC is the only induction heater
. . . with filament voltage regulation of 1%, assuring long tube life and precise repetitive production results.

which generator offers you most for the money?

*THER-MONIC GENERATOR "C" SERIES

THER-MONIC is the only induction heater
. . . providing complete access for maintenance from two sides of the cabinet.

THER-MONIC is the only induction heater
. . . whose frequency can be increased to 5,000,000 cycles by minor modifications, for the jobs that are difficult to heat with conventional frequencies.

THER-MONIC is the only induction heater
. . . with electrical and mechanical interlocks for maximum safety to equipment and personnel.

These and 20 other

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engineering achievements tell you here is the most generator* for your money.
Why not nail down all the facts? . . . Write for literature.

INDUCTION HEATING CORPORATION
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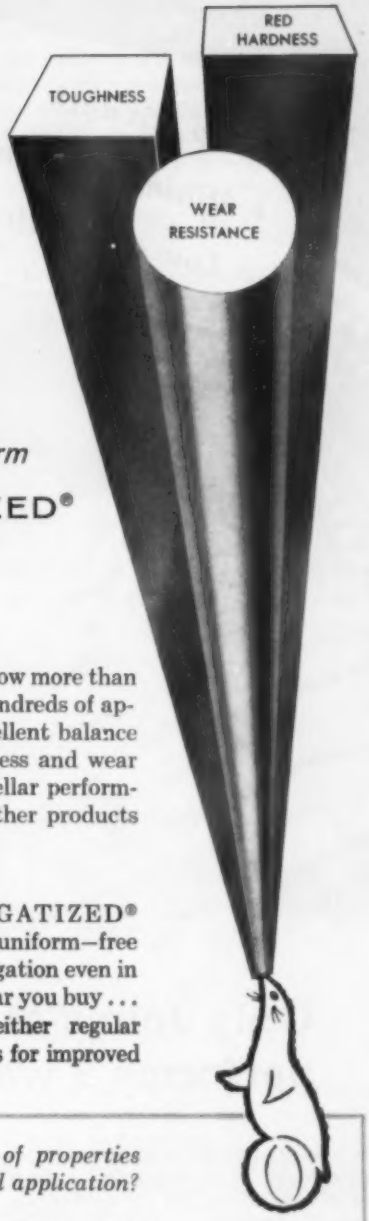
Producers of the most complete line of Induction and Dielectric Heating Equipment
ELECTRONIC • MOTOR GENERATOR • 60-180 CYCLE

Its balance makes the difference . . .

DOUBLE SIX M-2

HIGH SPEED STEEL



. . . a fully-uniform

DESEGATIZED® Steel

DOUBLE SIX M-2, now more than ever, is being used for hundreds of applications where its excellent balance of toughness, red hardness and wear resistance pays off in stellar performance of the tools and other products made from it.

Naturally, DESEGATIZED® Double Six M-2 is fully uniform—free of harmful carbide segregation even in the center areas of the bar you buy . . . and it's available in either regular analysis or XL® analysis for improved machinability.

Need better balance of properties for your high speed steel application? Call Latrobe today— ask for Double Six M-2!

Metalmasters . . .

behind every bar of Latrobe High Speed Steel

- Electrite Double Six M-2*
- Electrite Crusader*
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- Electrite No. 1*
- Electrite Tatmo*
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- Electrite TNW*
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**Available in regular analysis or XL® analysis for improved machinability.*

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LATROBE STEEL COMPANY

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Superex is easily combined with other insulations such as Johns-Manville Thermobestos®, J-M 85% Magnesia or J-M Insulating Fire Brick.

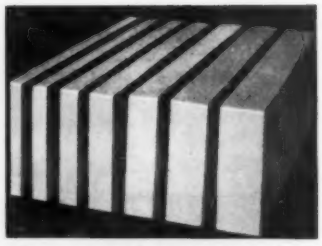
Only Johns-Manville Superex insulation performs 3 ways better at high temperature!

Few industrial products are so outstandingly superior, or so widely used in their area of application, as Johns-Manville Superex® Insulation.

A block insulation formulated of diatomaceous silica and asbestos for furnace and other applications, Johns-Manville Superex brings many advantages to high-temperature service—each contributing to reduced construction, maintenance and operating costs.

Superex is installed with measurable savings in time and labor! It is easy to cut and handle . . . weighs only 2 lbs. per sq. ft. per inch thickness . . . available in a wide variety of large block shapes and sizes. At high temperature—the material's excellent insulating value, thermal stability and resistance to shrinkage keep fuel costs low. Equally important—Superex saves on maintenance, too . . . easily withstands the daily abuse of normal service.

Send for your copy of IN-190A, the 12-page design and technical data brochure. It lists suggested applications—gives complete heat transmission tables and performance data. *Write for it today.* Address Johns-Manville, Box 14, N.Y. 16, N.Y. In Canada, Port Credit, Ont.



Saves waste. Superex comes in 7 standard thicknesses from 1" to 4". Other sizes available on order.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS

pair 'em up

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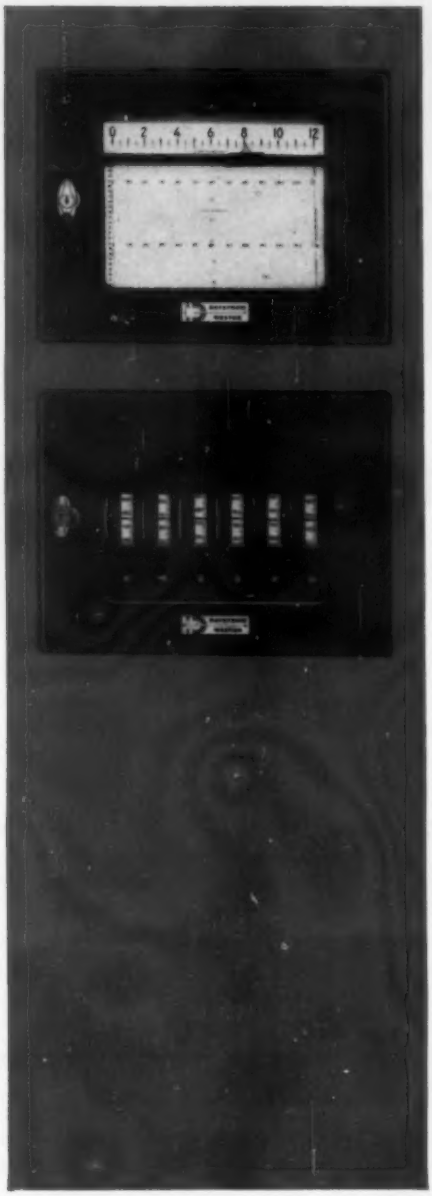

Looking for savings, without sacrifice of quality, in a multi-unit control and recording installation? If so, this Daystrom-Weston "package" is for you. Both units are exceptional in their own right . . . the most compact, maintenance-free, versatile instruments available. Together, the Model 6702-6134 combination costs less per point than any other type of recording-controlling potentiometric instruments. Both units employ the D-Pak® Constant Current Source, eliminating all standardizing mechanisms.

The Model 6134 Non-Indicating Multipoint Controller and the Model 6702 Multipoint Recorder each accommodate up to 6 separate imputs. (The latter can record as many as 18 additional points if desired.) Each control unit is unitized and independent . . . provides precise 2- or 3-position electric contact control.

Two distinctly separate circuits afford dual protection on overtemperature. Alarm circuits set for individual points in the Recorder provide high or low temperature cut-off as desired. Two separate or one common thermocouple can be used for each point – as the installation demands.

Control packages, including panels and accessories, can be suited to your specific application.

This exclusive space saving combination provides the finest in precision performance with

unmatched low cost!

For further information, contact your local Weston representative . . . or write to Daystrom-Weston Sales Division, Newark 12, N. J. In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.

DAYSTROM WESTON

World leader in measurement and control

DAYSTROM-WESTON INDUSTRIAL INSTRUMENTS include a full line of recording and controlling potentiometers with strip and circular charts; mechanical recorders and indicators for pressure, temperature and flow; and non-indicating controllers, both electric and pneumatic.

Riehle-Losenhausen Fatigue Testing Equipment applying stress to 60" concrete beam in Department of Theoretical and Applied Mechanics, College of Engineering, University of Illinois. This equipment is being used in a three-year study of cumulative fatigue damage to concrete as used in highways.

Machine duplicates actual stress-and-rest conditions

Flexural stresses of varying magnitude and sequence are delivered to material specimens and assemblies by this RIEHLE-LOSENHAUSEN fatigue testing equipment which simulates functional fatigue conditions. The basic system consists of a control console, a pulsator, a programmer and separate loading cylinders.

Loads of varying magnitude are followed by either rest periods or by application of high static overloads.

TESTS ENTIRE ASSEMBLIES

Through the use of a steel testing stand, the RIEHLE-LOSENHAUSEN machine easily accommodates complete structural assemblies such as the following: wings, fuselages, tails and other components of aircraft frames; machinery and engine parts and assemblies; hull sections of ships; girders and joints of bridges; pre-stressed concrete beams and built-up timbers. Separate loads can be applied at various points.

Whatever your materials testing problems might be, there is a RIEHLE complete standard machine or custom built unit to meet your strictest requirements. Capacities range from 10,000 to 400,000 pounds.

ALSO FROM RIEHLE . . . Hydraulic and Screw Power Universal Testing Machines, Creep, Stress Rupture and Fatigue Testing Machines, Impact, Brinell, Torsion, Construction Materials, Horizontal Chain, Rope and Cable Testing Machines, Portable Hardness Testers for Rockwell Readings, etc.

Riehle® TESTING MACHINES

DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

"One test is worth a thousand expert opinions" TM

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RIEHLE TESTING MACHINES
Division of American Machine and Metals, Inc.
Dept. MP-759, East Moline, Illinois

Please send free literature on RIEHLE Testing Machines.

_____
(Type of Machine)

NAME _____

COMPANY _____

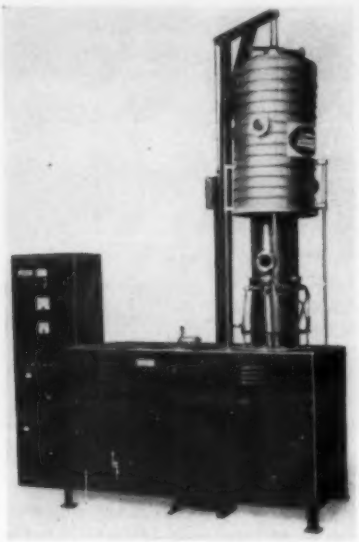
ADDRESS _____

CITY & ZONE _____ STATE

APPLICATION and EQUIPMENT new products

High Vacuum System

Kinney Mfg. Div. has announced a high-vacuum system that will attain pressures of 1×10^{-9} mm. Hg or better within a stainless steel chamber 12 in. in diameter by 18 in. high. The work chamber is enclosed in a



mild steel outer chamber which has two mating observation ports and is fitted with heating elements, radiation shields and wrapped with water-cooling coils. The outer chamber is evacuated to the 10^{-4} range and the work chamber to an ultimate pressure of 1×10^{-5} mm. Hg.

For further information circle No. 1 on literature request card, page 48-D.

Nickel Alloy

A new nickel alloy, developed as a container material for molten fluoride salts, has been announced by Haynes Stellite Co. The alloy has 6 to 8% Cr, 15 to 18% Mo, 5% Fe, 0.5% Si, 0.8% Mn, 0.4 to 0.08% C, small amounts of Al, Ti, B and S, remainder nickel. Its resistance to embrittlement on continuous exposure to temperatures up to 1600° F. and corrosion resistance suggest its applicability to high-temperature corrosion service. Alloy N is weldable and can be forged. The hot working range is between 1600 and 2150° F. It has been extruded and produced as tubing.

For further information circle No. 2 on literature request card, page 48-D.

Portable X-Ray

A 50-lb. industrial X-ray generator small enough to pass through a 6-in. opening but powerful enough to radiograph 1¼ in. of steel in 45 sec. has been announced by Picker X-Ray Corp. The Andrex 140 kv. X-ray unit can be operated on practically any available power-supply line. The unit consists of two parts, the 50-lb. generator and the 55-lb. control. The unit control makes it possible for the operator to choose any technique within a range of 50 to 140,000 volts and 1 to 4 ma.

For further information circle No. 3 on literature request card, page 48-D.

Welding

A new welding process called Short-Arc welding has been announced by Linde Co. This new inert-gas consumable-electrode process will fusion weld all common metals in thicknesses of 0.030 to 0.100 in. in all positions and types of joints. The process uses constant potential power supplies incorporating a drooping characteristic to control surge currents to limit the time duration of arc outages, prevent wire ejection, and produce a stable buzzing type of arc. This arc, operating in the range of 30 to 125 amp.,

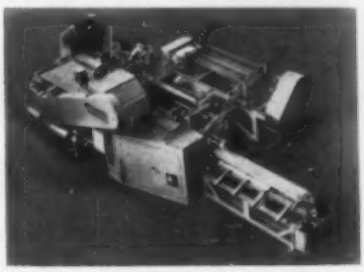
14 to 19 v., short circuits dozens of times per second. This produces a small cold puddle pinpointing the location of the arc heat and permitting the welding of thin materials. It is used primarily with 0.030-in. wire.

For shielding, argon has been found suitable for most metals such as aluminum, copper, and Everdur. For stainless steel and carbon steel, argon-oxygen and argon-carbon dioxide mixtures are used. Pure carbon dioxide is being used for some steel applications, but it produces somewhat more spatter and poorer bead formation.

For further information circle No. 4 on literature request card, page 48-D.

Automatic Forging Machine

The Hill Acme Co. has announced a fully automatic forging machine integrated with an induction heater which will produce ⅝ and ¾ in. mine-roof bolts in lengths from 12 to 72 in. at the rate of 45 pieces per min. The rods, already threaded at one end, are first fed through the induction fur-



nace. Heated rods are delivered to the forging machine where they are gaged for length, picked up by fingers and passed progressively through the four position die. The finished forgings are discharged from the back of the machine. Pieces longer than 36 in. are supported by a walking beam.

For further information circle No. 5 on literature request card, page 48-D.

Peening

A new peening method that uses a stream of glass beads, microscopic in size and electrostatically suspended in a solution, has been announced by Aero-Test Equipment Co. Peening is done much the same as shot peening except that the glass spheres are electrostatically suspended in the solution to provide uniform impact distribution. Variation can be made in size of spheres, force of peening stream, and duration of peening. Scale, corrosion,

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ULTRASONICS
The one-third acre dish of this huge radio telescope, being built by E. W. Bliss Co., turns on a 22-foot support bearing. Sperry ultrasonic testing was used to search the bearing's eight 4-inch plates for laminations and to thoroughly probe the vital welds.
WELD
5 FT
10 FT

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dirt, burrs and tool marks can be removed without altering the dimensions of the part. Perfecto-Peen does not leave imbedded particles in the object being peened and does not nick sharply machined edges or threads. The glass beads level and surface work the metal for increased fatigue life and finer finish.

For further information circle No. 6 on literature request card, page 48-D.

Flat Polisher

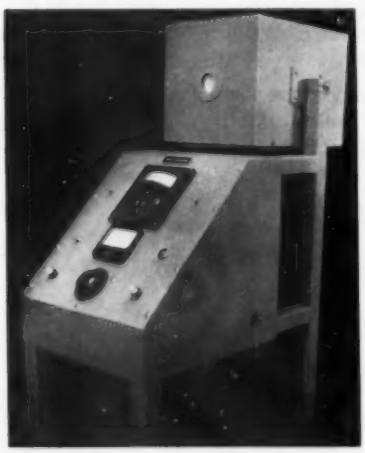
Murray-Way Corp. has announced a flat polisher, designed to grind, polish and deburr flat surfaces of material with cross sections up to 12 by 4 in. The machines will handle metal in coil,

sheets, bars, blanks, manufactured or cast parts, using an abrasive belt for either wet or dry operation. Belt tension and oscillating idler roll pressure are held constant by automatic air control.

For further information circle No. 7 on literature request card, page 48-D.

Heat Treating Furnace

Materials Research Corp. has announced a multi-purpose furnace for heat treating and experimental laboratory work. It may be used in either a horizontal or vertical position at temperatures to 2000° F. A clock motor is mounted for use in the growth of single crystals by the Bridgman technique. Furnace cores may be replaced within 2 min. while the furnace is still at temperature. An anticipating controller, variac and ammeter are provided with the furnace.



For further information circle No. 8 on literature request card, page 48-D.

Strain Gages

Three new strain gages of rosette shape have been announced by Tatnall Measuring Systems Co. Two of the gages are fully temperature-compensated for steel, 18-8 stainless steel, magnesium alloys and aluminum; the third is not. The smallest gage measures 1/32 in. wide, 5/32 in. long and 0.001 in. thick; the largest is ½ in. square and also 0.001 in. thick. Weight of the gages ranges from 1.1 to 9.3 mg. The rosette shape helps to determine magnitude and directions of principal strains; miniature size permits use in areas of very steep strain gradient; high fatigue life of the gages allows testing of structures undergoing severe dynamic strains.

For further information circle No. 9 on literature request card, page 48-D.

Ultrasonic Welder

A new instrument-type ultrasonic welder designed to make welds in small parts and delicate assemblies has been announced by Aeroprojects. This unit has a power capacity of 100

watts. Ultrasonic welding is accomplished without melting or fusion and no electrical current passes through the parts being joined. Ultrasonic welding permits joining of silicon or germanium and aluminum or gold wire. Electric match and other fine bridge wire assemblies using high resistance wire in the thickness range of 0.003 to 0.001 in. can also be welded.

For further information circle No. 10 on literature request card, page 48-D.

Magnesium Alloy

A magnesium die-casting alloy for service above 500° F. has been announced by the Dow Chemical Co. The alloy contains about 1% Th, 1% Mn, balance Mg and is designated

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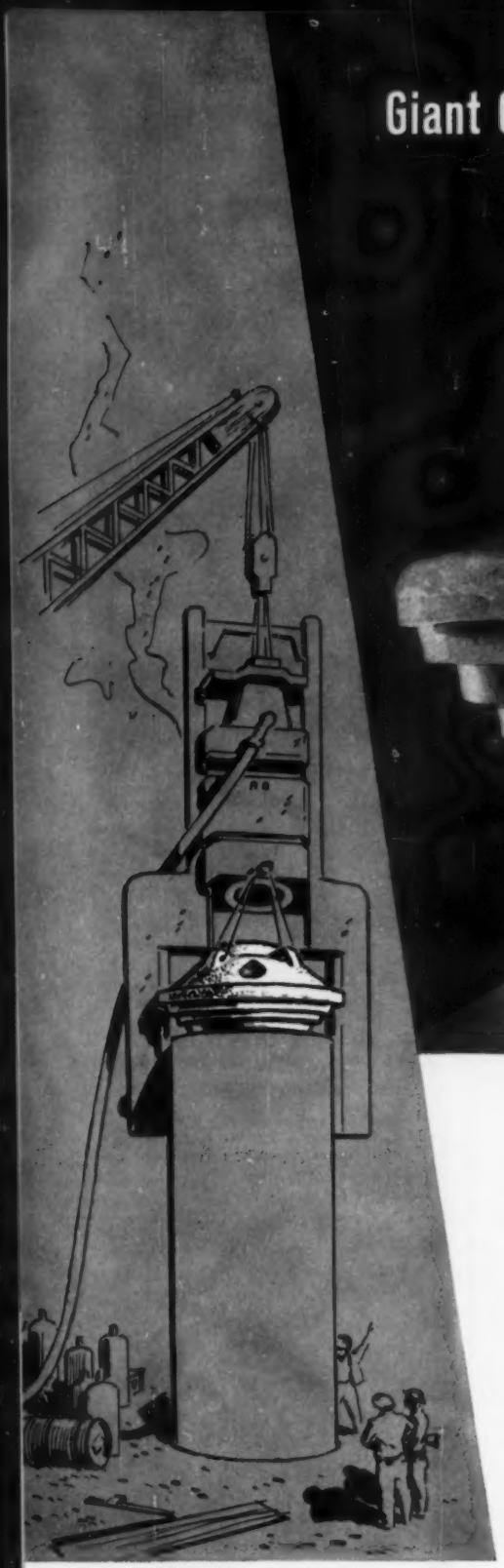

If this 17,540 pound cast steel pipe cap were not used to set a string of oil well casing, it could be mistaken for a gigantic spinning top. Either way, here is visual proof of the diverse requirements for industrial steel castings which are satisfied by the experienced engineers, metallurgists and skilled foundrymen of Erie Forge & Steel Corporation. From the open hearth melt through the machining operation to the shipping dock, close quality control is our prime concern.

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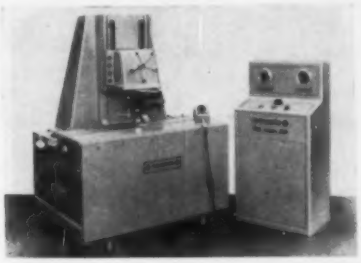
HM11XA. The new alloy retains good mechanical properties through 800° F. It has a density of 0.064 lb. per cu. in. Separately die-cast test bars of the new alloy exhibited average tensile strength of 30,200 psi. at 70° F., 16,800 psi. at 400° F., 12,400 psi. at 600° F. and 7800 psi. at 800° F.

For further information circle No. 11 on literature request card, page 48-D.

Fatigue Tester

A new series of fatigue testing machines has been announced by Cosa Corp. This new series of four sizes covers a load range from 1200 to 400,000 lb. and a frequency range from

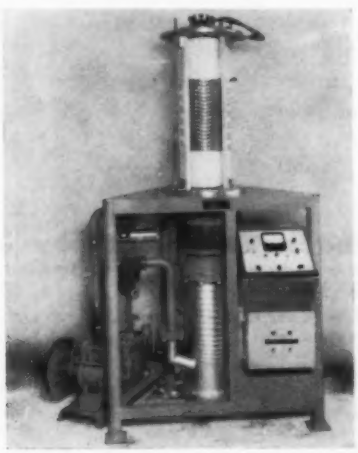


600 to 10,000 cycles per minute. The large stroke of these models enables them to test very soft materials with low frequency, and rigid parts such as gear wheels, connecting rods, steel test bars with high frequency. It also extends the machines' application to torsion and bending tests. The test frequency can be selected to expose the part as close as possible to actual operating conditions by means of the variable speed drive. It can also be set to maximum for fast results on S-N curve investigations.

For further information circle No. 12 on literature request card, page 48-D.

Vacuum Furnace

A new quartz-tube furnace and pumping system designed for laboratory melting, heat treating or sintering operations up to 5400° F., at pressures of 0.01 micron has been announced by Vacuum Specialties Co. High-frequency power supply and control is an optional feature. A 6-in. oil diffusion pump has a water-cooled or refrigerated cold trap. The top cover of the furnace is built in two sections, one hinged, the other semipermanently mounted to the quartz tube. It is not necessary to disassemble the furnace to load and unload it. A shielded sight port with wiper is provided for observation and measurements.



For further information circle No. 13 on literature request card, page 48-D.

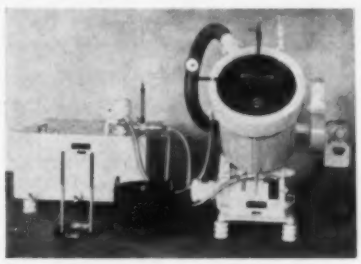
Protective Coating

Heatbath Corp. has announced a new coating liquid containing complex corrosion inhibitors and water soluble polymers. Solutions are made by adding 2 parts of water to 1 part of Duralak. This protective coating can be applied by immersion, brush or spray.

For further information circle No. 14 on literature request card, page 48-D.

Chromium Plater

The Dawson Corp. has announced a new barrel chromium plater featuring a choice of different mesh plating baskets, adjustment of barrel angle



and an adjustable anode. The unit will process parts of varying shapes, sizes and weights in loads from 5 to 10 lb.

For further information circle No. 15 on literature request card, page 48-D.

Ultrasonic Cleaner

A mobile ultrasonic cleaning system has been announced by Acoustica Associates, Inc. The units can be pushed from one location to another for use wherever electric power is available. Cleaning tanks with up to 75 gal. capacity and ultrasonic power generators in ratings up to 2500 w. can be provided. Power may be derived from a 115 or 220 v. a-c. outlet.

For further information circle No. 16 on literature request card, page 48-D.

Testing Furnace

The Zirconium Corp. of America has announced a laboratory pot furnace featuring a bottom drop hearth and

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FLO-METERS FOR ALL INDUSTRIAL GASES

If you use industrial gases in heat treating or processing, then you should have the Waukee Flo-Meter Catalog — Bulletin 204 in your files. For the accurate flow measurement of air and industrial gases, Waukee provides meters from 3 C.F.H. to 25000 C.F.H.

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Complete capacity tables are shown in Bulletin 204 and we will be glad to send it along with prices. Write Waukee Engineering Co., Inc., 5140 North 35th Street, Milwaukee 9, Wisconsin. R.C.O.

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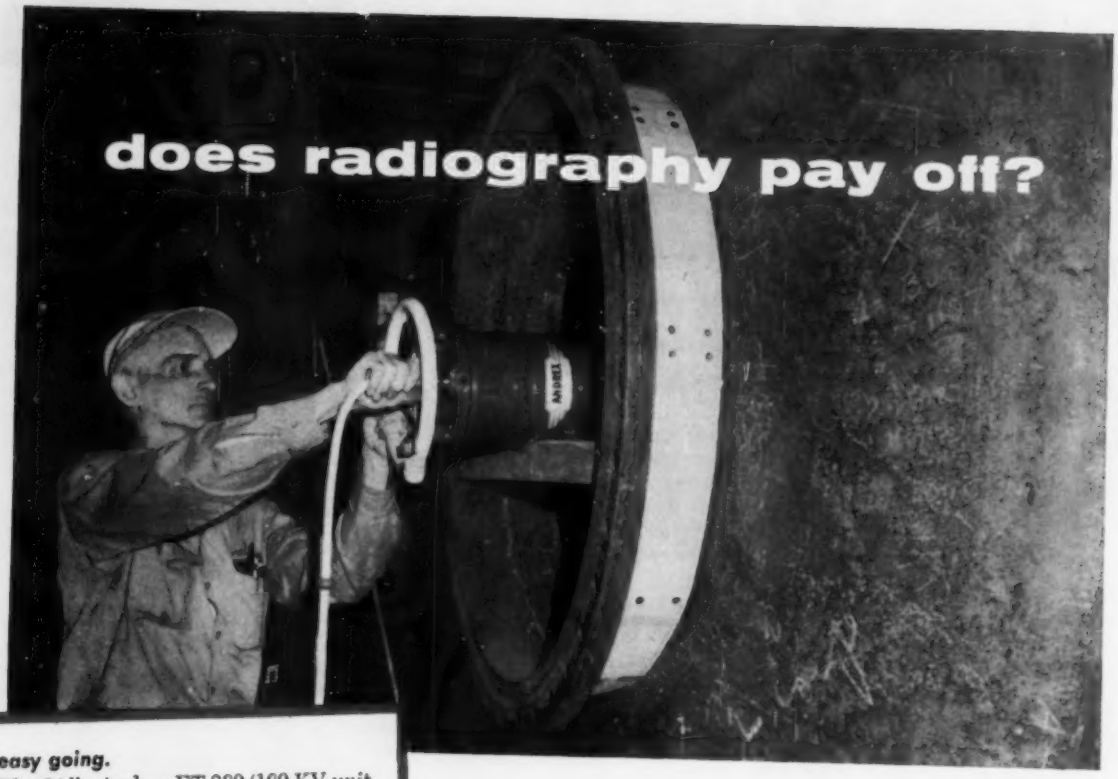
does radiography pay off?



easy going.
The 64 lb. Andrex FT 360/160 KV unit here emits full-circle radiation: it will radiograph the entire girth weld of a vessel in one "shot". Films are held in place by a snap-on canvas band circling the neck.

x-ray is best for some jobs.
In that case the right machine for you probably lies somewhere in the comprehensive range of x-ray units listed below.

gamma ray (from radioisotopes) is better for others.
With one machine or another in the broad Picker line of isotope units you can radiograph anything from thin aluminum up to 10" thick steel.

unbiased advice free for the asking.
With an equipment line like that (nothing like it in the field) we have no axe to grind for any particular kind of machine: we can *afford* to be unbiased.

Does radiography pay off? Ask steel tank and pressure vessel fabricators—from now on in they couldn't *live* competitively without it.

Look: the new ASME code, Section VIII, ascribes 100% efficiency to a welded joint radiography-proved sound: the weld is considered strong as the mother metal even without stress-relieving. Which means that steel thickness of a radiographed vessel can be less than the thickness of a non-radiographed one.

Ergo: radiography can save tons of steel.
Ergo: radiography saves far more than it costs.

An extreme example? Hardly: hundreds of case records are as dramatic. Call in your local Picker man to find out what radiography (or fluoroscopy, maybe) can do for you. You'll find Picker offices in all principal cities (see local phone book) or write or wire us at the address below.

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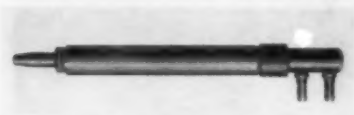
tripod stand. An oxygen-acetylene or an oxygen-natural gas burner can be employed for firing this unit. Furnace shell temperature is 250° F. when the firing chamber is at 4600° F. using the oxygen-acetylene burner. Heating chamber is 6 in. high by 8 in. deep. The hot pot can be used to perform thermal shock tests as well as hot load and tensile tests. The furnace shell is removable from the base and can be used separately in conjunction with physical testing equipment.

For further information circle No. 17 on literature request card, page 48-D.

Welding Holders

Ejector-type spot welding tip holders have been announced by Air Reduction Sales Co. as part of the Tuffaloy resistance welding line. They consist of a plated copper alloy barrel and a brass head carrying the water



hose connectors held together by a coupling. An ejector tube, assembled to the head, ejects the welding tip when the entire head is forced to slide into the barrel. Two rubber water seals are inside the barrel, well away from dirt and damage.

For further information circle No. 18 on literature request card, page 48-D.

Gas Dryer

For drying gases at pressures of 1000 to 6000 psig., the C. M. Kemp Mfg. Co. has announced a new series of desiccant dryers. These high pressure dryers are designed to dry air, oxygen, carbon dioxide, argon, helium, and hydrogen to dew points as low as −160° F. They are adsorptive-type dehydrators which remove moisture by passing compressed gases through a bed of granular desiccant such as silica gel, activated alumina or molecular sieves.

For further information circle No. 19 on literature request card, page 48-D.

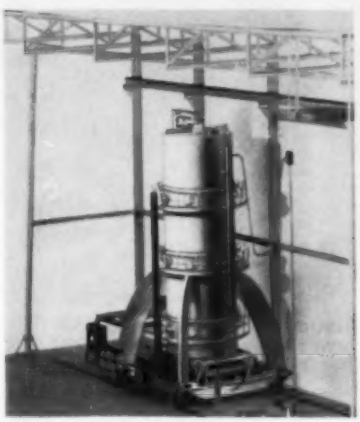
Finishing Compound

Esbec Barrel Finishing Corp. has announced a new type of neutral, nonabrasive compound for barrel finishing operations. Esbec No. 134 in many cases replaces acid compounds and eliminates the necessity for subsequent neutralizing. Used with chips or steel media, it cleans, bleaches, descales and burnishes. It will remove rust or other oxides from steel or alloys, and will bleach, clean or burnish steel, copper, brass, beryllium copper, and many stainless steels.

For further information circle No. 20 on literature request card, page 48-D.

Heat Treating

Commercial Steel Treating Corp. has announced a heat treating furnace to process large parts for rockets and missiles. The new furnace is of vertical, drop-bottom design and stands over 42 ft. above floor level on a specially designed gantry-type mobile car. It is of the gas-fired radiant-tube type with a controlled atmosphere and is capable of clean hardening or gas carburizing a part 70 in. in diameter and



28 ft. long, weighing up to 4 tons. The operating temperature of the furnace will be 1850° F. with provision for higher temperatures if desired. A recirculating fan located in the moveable bottom cover circulates heat and atmosphere. The furnace travels under its own power to quench its load into oil, water or nitrogen gas quenching pits 40 ft. below floor level.

For further information circle No. 21 on literature request card, page 48-D.

Zirconium-Copper Alloy

A new zirconium-copper alloy has been announced by American Metal Climax, Inc. Amzirc alloy consists of high-conductivity, oxygen-free copper and carefully controlled concentrations of high purity zirconium. This new alloy should find widest use in electrical equipment where there is a need for the combination of high electrical

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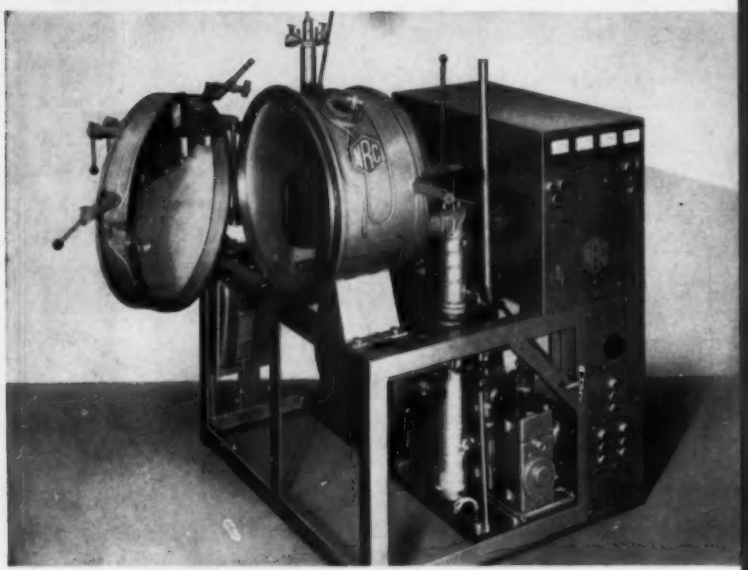
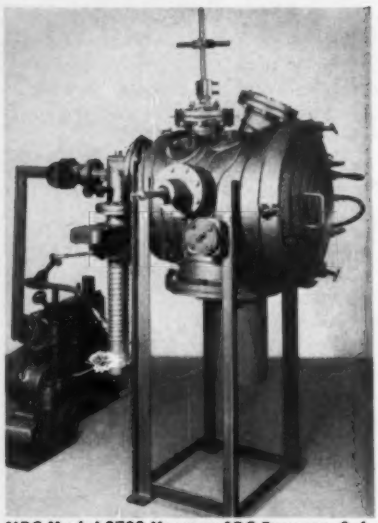
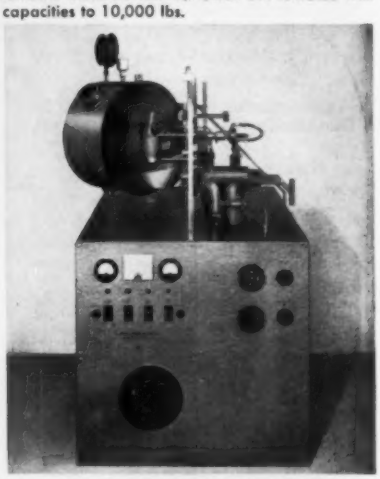


NRC Model 2551 Vacuum INDUCTION Furnace. Packaged facility for melting, purifying, alloying, casting and heat treating. Capacity 12 lbs. Other standard and special induction furnaces with capacities up to 5000 lbs.



NRC Model 2703 Vacuum ARC Furnace. Safe and versatile unit for consumable or nonconsumable electrode melting into cold mold or skull (consumable head not shown). Other arc furnaces with capacities to 10,000 lbs.



NRC Model 2904-B Vacuum RESISTANCE Furnace. Over 100 now in use for melting, purifying, alloying, casting, sintering, brazing, annealing, and heat treating. Capacity 2-8 lbs. Temperature above 2000°C. Pressures to 10^{-5} mm Hg. Other standard resistance bell, muffle, and pit furnaces with hot zones to 54" dia. by 12'.

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What type of furnace would be most suitable for your program.
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conductivity and good mechanical strength at elevated temperatures. A typical bar of Amzirc, cold worked 60% and aged for one hour at 750° F. has a tensile strength of 63,000 psi., yield strength of 59,000 psi., elongation of 12%, and electrical conductivity of 90 to 95%. At 750° F., the short time tensile strength is 46,500 psi.

For further information circle No. 22 on literature request card, page 48-D.

Titanium Alloy Tubing

Titanium alloy 3 Al-2.5 V is now available as small tubing according to announcement from Superior Tube Co. Suggested applications for this tubing are for aircraft and missile parts where a high strength-to-weight ratio is desirable and for process equipment where strength and corrosion resistance are needed. Annealed 3 Al-2.5 V tubing has a yield strength of 85,600 psi. In the full hard drawn condition, it has a yield strength of 118,000 psi. Nominal chemical composition of the alloy is 3% Al, 2.7% V, 0.02% Si, 0.16% Fe, 0.01% Mn, 0.02% C, 0.015% N, 0.011% H, balance Ti.

For further information circle No. 23 on literature request card, page 48-D.

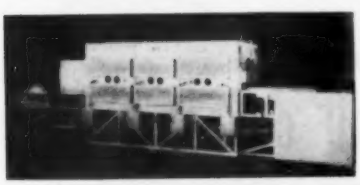
Welding Electrode

The Lincoln Electric Co. has announced a new E-6012 electrode with a moderate amount of iron powder and arc-stabilizing ingredients in the coating. The electrode, Fleetweld 7MP, is classed as an all-position, a-c. and d-c., mild steel electrode. It is said to combine the ease of operation, good bead appearance and a-c. operation of an E-6013 electrode with the higher speeds and lower cost of an E-6012 electrode. The electrode is available in the ⅛ to 5/16-in. sizes.

For further information circle No. 24 on literature request card, page 48-D.

Electric Furnace

A new electric furnace for applying electroluminescent coatings has been announced by Pereny Equipment Co. This new furnace has three-zone control. Power controls of the saturable-reactor type maintain an even heat. The continuous mesh belt of high-



temperature alloy is operated over stainless-clad rolls through a variable speed drive. Silicon carbide heating elements located over and under the work are arranged for easy replacement without interrupting production. When straight-line production is essential a number of these furnaces are used, separated by the number of porcelain enamel spray booths necessary to apply the successive multiple coatings required in the process.

For further information circle No. 25 on literature request card, page 48-D.

High-Temperature Furnace

Lucifer Furnaces, Inc., has announced new box-type furnaces with heating elements that produce temperatures to 3190° F. Resistance of the elements does not change with use.

The furnaces are complete and include an automatic controller (indicating and controlling), platinum-rhodium thermocouple, magnetic contractor, and other accessories.

For further information circle No. 26 on literature request card, page 48-D.

Refractory

Refractories Div., H. K. Porter Co., has announced a new 80% alumina plastic refractory that combines the advantages of monolithic construction with the advantages of plastic construction (air and gas tight, no special shapes needed, high thermal shock resistance). Pitco 80 is recommended to balance refractory linings in high-temperature furnace installations, and for linings where iron oxides and molten aluminum cause failure.

For further information circle No. 27 on literature request card, page 48-D.

Plating Fixtures

Commercially pure titanium anode hooks and baskets to meet the need for corrosion resistance in nickel and chromium plating operations have been announced by Mallory-Sharon Metals Corp. Both hooks and baskets are available in standard sizes and shapes. Standard titanium hooks range in size from 3½ to 8 in.

For further information circle No. 28 on literature request card, page 48-D.

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Really Tough Where the Power Hits the Ground– thanks to TOCCO* Induction Heating

The Eimco Corporation of Salt Lake City manufactures heavy-duty earth moving and mining equipment of many kinds. All of their equipment must be engineered for tough work in the roughest kind of terrain, and all of it runs on tractor track that must stand up to the toughest abuse.

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Recently Eimco installed a 100 kw, 10,000 cycle TOCCO machine for heat treating track links. This equipment assures a completely uniform hardness pattern—the same every time for one link or one million. Furthermore, the parts are drawn as well as hardened by one TOCCO machine with one operator.

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In addition to superior quality, TOCCO increased track link production over 400%. Formerly, one man could produce 35 links per hour; now, with TOCCO, he produces 150!

Whether you're looking for product improvement, increased production, or lower unit costs, it will pay you to investigate TOCCO Induction Heating.

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Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating."

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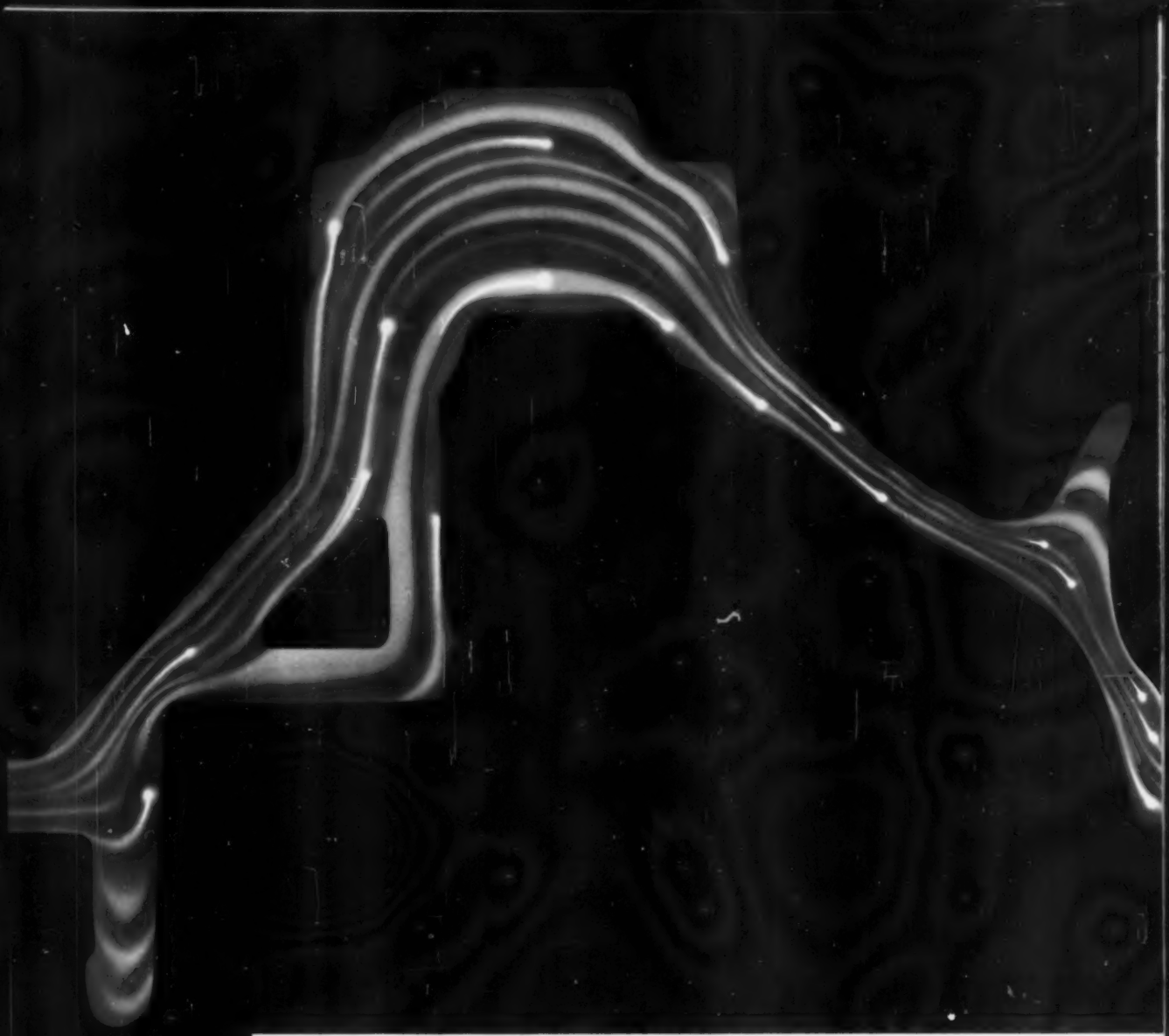


Fluid mapper pattern demonstrating liquid flow through a cross section of a Malleable differential carrier.

Versatility is Malleable

The ability to do most any job well is synonymous with Malleable iron castings. The variety of tasks they perform, from the commonplace to the spectacular, is legend. The strength and toughness . . . the freedom of design . . . the wide range of shapes and sizes . . . the excellent machinability . . . the economies achieved . . . all these advantages of Malleable combine to create an unexcelled reputation for versatility.

Whatever your needs, look first to Malleable.

For information or service, call on one of the progressive firms that identify themselves with this symbol—

MEMBER
MALLEABLE
CASTINGS COUNCIL

If you wish, you may inquire direct to the Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio, for information.

Versatility Is Key to Malleable's Increasing Use

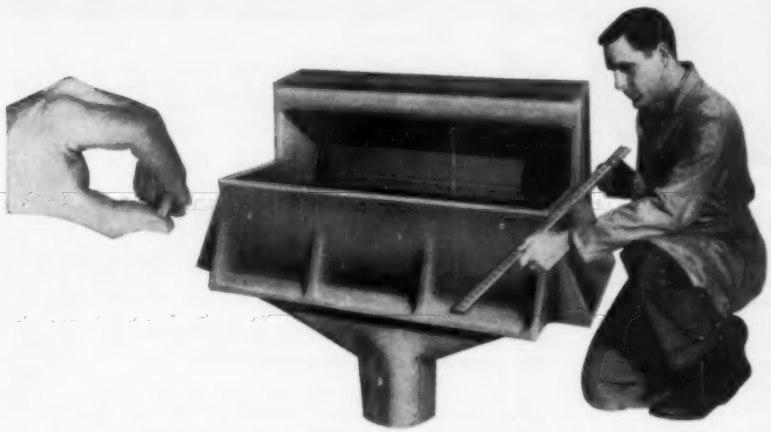
Recent metallurgical advances have made the Malleable irons a family of metals uniquely capable of meeting the most diverse design, production and performance requirements. Whether the vital consideration is high strength, toughness, ductility, hardness, machinability, high or low temperature performance, wear resistance, or economy and adaptability for complicated designs, Malleable castings have the versatility to meet exacting specifications.

For versatility of shape, the casting process is unexcelled. It permits direct production of the most complicated components. The metal is placed exactly where it is needed regardless of the intricacy of the design.

The capabilities of the metal to be cast are of even greater significance, for every application has a different set of requirements. Here, Malleable iron provides unique opportunities to obtain better parts at less cost.

Holes can be punched in Malleable, surfaces can be coined to meet rigid specifications. The pearlitic Malleables can be surface-hardened for even better wear resistance. These and other advantages make today's Malleable iron one of the most versatile engineering materials available.

Although Malleable iron's properties are flexible, depending on service requirements, certain relationships remain constant. Malleable provides more strength and toughness per dollar than any other metal. It is also the most machinable of all ferrous metals of similar properties.



Malleable castings can be produced in sizes ranging from the hammer handle wedge, shown here, weighing less than an ounce, to the 1,125 pound bridge scupper. Throughout this range is an endless variety of castings, best made of Malleable for highest quality at lowest cost.

Shapes and sizes of Malleable castings are virtually limitless. The combination of Malleable's good castability with modern production techniques regularly results in sections as thin as 1/16" and tolerances of ±.005" per inch in sections of 1", with excellent surface finishes.

Engineering Aids Available

While the design of Malleable castings is not complicated, it will pay you to consult a skilled Malleable engineer who can offer time and cost saving suggestions for the production of better parts. As another aid to basic Malleable casting design, a special folder — *Data Unit 104 — Design Versatility* — is available from any member of the Malleable Castings Council and from the Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

These companies are members of the

MALLEABLE CASTINGS COUNCIL

CONNECTICUT
Connecticut Mall. Castings Co., New Haven 6
Eastern Malleable Iron Co., Naugatuck
New Haven Malleable Iron Co., New Haven 4

DELAWARE
Eastern Malleable Iron Co., Wilmington 99

ILLINOIS
Central Fdry. Div., Gen. Motors, Danville
Chicago Malleable Castings Co., Chicago 43
Moline Malleable Iron Co., St. Charles
National Mall. and Steel Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Link-Belt Company, Indianapolis 6
Muncie Malleable Foundry Co., Muncie
Terre Haute Mall. & Mfg. Corp., Terre Haute

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
Albion Malleable Iron Co., Albion
Auto Specialties Mfg. Co., Saint Joseph
Cadillac Malleable Iron Co., Cadillac
Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
Northern Malleable Iron Co., St. Paul 6

NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW JERSEY
Meeker Foundry Company, Newark 4

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division Eastern Malleable Iron Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

OHIO
American Malleable Castings Co., Marion
Canton Malleable Iron Co., Canton 5
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div., Columbus 16
Maumee Malleable Castings Co., Toledo 5
National Mall. and Steel Castings Co., Cleveland 6

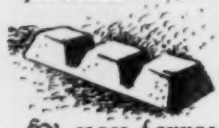
PENNSYLVANIA
Buck Iron Company, Inc., Philadelphia 22
Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

TEXAS
Texas Foundries, Inc., Lufkin

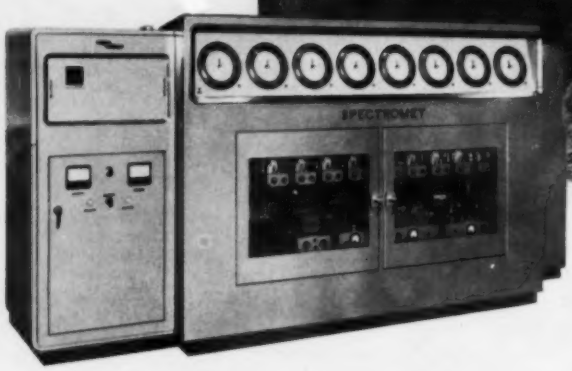
WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

WISCONSIN
Badger Malleable & Mfg. Co., S. Milwaukee
Belle City Malleable Iron Co., Racine
Chain Belt Company, Milwaukee 1
Federal Malleable Company, West Allis 14
Kirsh Foundry Inc., Beaver Dam
Lakeside Malleable Castings Co., Racine
Milwaukee Malleable & Grey Iron Works, Milwaukee 46

ferrous



& non ferrous



SAVINGS

in the melt shop by quick analysis with the

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CHEMICAL COMPOSITION IN MINUTES
NO LABORATORY REQUIRED

The Baird-Atomic SPECTROMET allows high precision analysis of alloying and minor elements to be made quickly and easily. Results are reported to the melt shop in minutes permitting corrections to be made prior to pouring. The expanded SPECTROMET is specially designed for rugged, practical use . . . to be operated by non-technical personnel.

SAVE MONEY, SAVE TIME, ELIMINATE WASTE

- Eliminate "off analysis" heats.
- Shorter furnace holding time permits more heats per month, minimum loss of alloy elements, longer furnace life, lower fuel costs.
- Conserve expensive alloying elements by confidently aiming at low side of the specification. Detect harmful tramp elements.
- Install close to the melt shop without need for special laboratory.
- Reduce expenses by saving manpower, supplies, and space.

Only the SPECTROMET offers all these features:

- Results presented on indicator dials directly in percent concentration.
- The *Automatic Optical Servo Monitor* to provide continuous compensation for variation in temperature and atmospheric pressure, vibration and shock.
- Parallel interchangeable read-out channels to increase reliability, facilitate maintenance.
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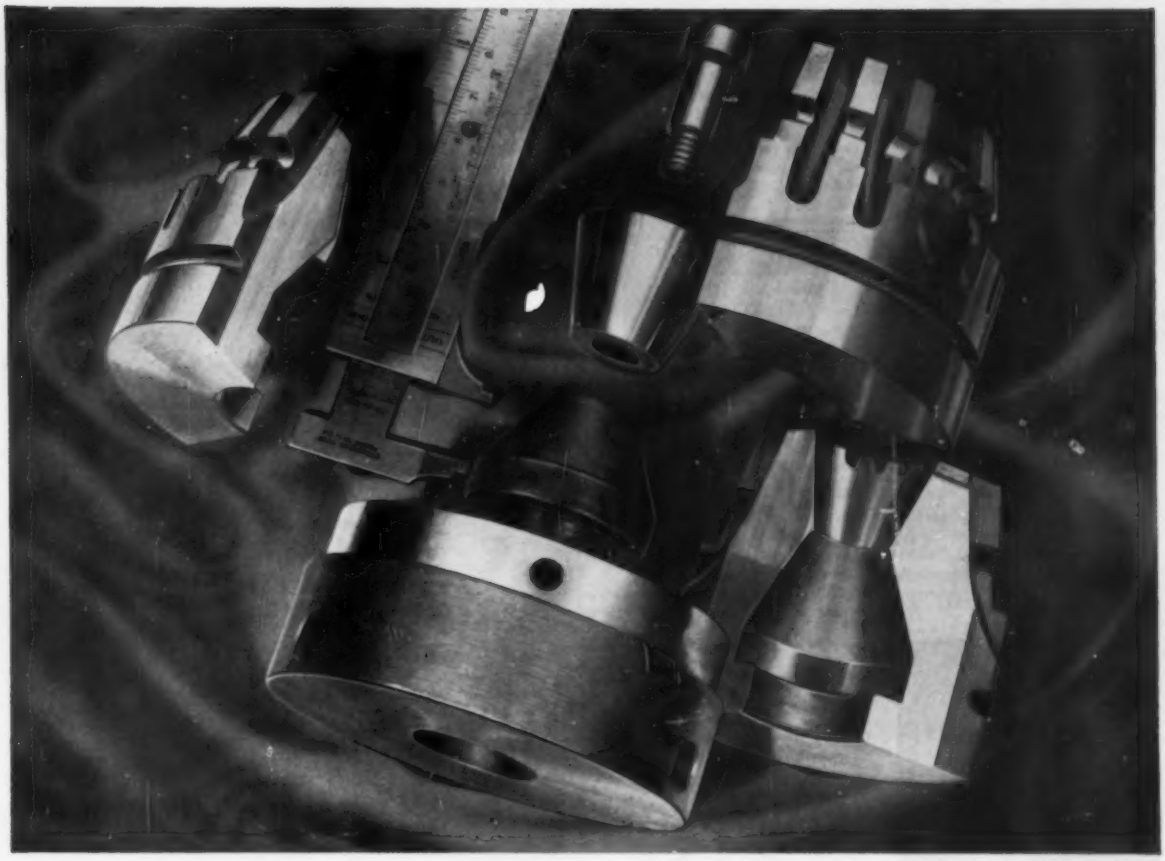

INTRICATE SHAPES MADE EASY WITH GRAPH-AIR®

hardens at 200° to 300° lower than most air-hardening tool steels

YOU can make intricate shapes like these easier and at less cost with versatile Graph-Air tool steel. Here's why:

1) **GRAPH-AIR AIR-HARDENS FROM AS LOW AS 1450°F.** That's as much as 400 degrees lower than most air-hardening tool steels. You reduce distortion, simplify heat treating control, minimize scaling and decarburization.

2) **GRAPH-AIR MACHINES FASTER.** The free graphite in its structure makes it machine 30% faster than ordinary tool steels. Means more production for you.

3) **GRAPH-AIR HAS MORE STABILITY.** It's one of the Timken Company's graphitic tool steels, the most stable tool steels ever made. Tests prove it. And that means longer accuracy for parts made of Graph-Air.

Uniform hardening, reduced distortion and all its other advantages allow you to machine Graph-Air into more intricate sections. It's a money-saving solution for blanking dies or other steel parts that must withstand abuse. For the best tool steel to make intricate shapes—the one that air-hardens at lower temperatures—specify Graph-Air. Available in solid and hollow bar sizes. Our metallurgists will help you select the most economical size for your needs. Write: The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steels and Removable Rock Bits.*

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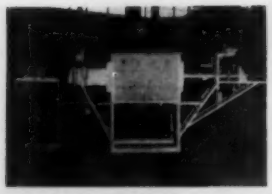
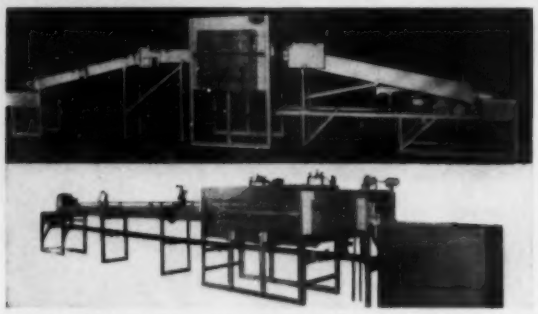
1. Quality that's uniform from heat to heat, bar to bar, order to order
2. Service from the experts in specialty steels
3. Over 40 years experience in solving tough steel problems

TIMKEN® *Fine Alloy* STEEL

TIMKEN GRAPHITIC STEELS ARE CARRIED IN STOCK BY 9 DISTRIBUTORS WITH 42 WAREHOUSES IN 31 CITIES IN THE UNITED STATES AND CANADA



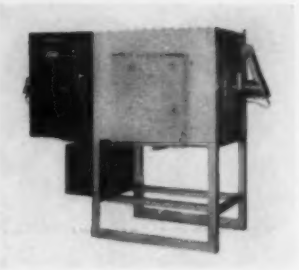
HAYES TYPE M-Y HIGH-TEMPERATURE FURNACES . . . provide uniform heating for sintering ceramics, cermets and refractory metals at temperatures over 3000°F. Economical — can be used with reducing atmospheres for close-control research or full-scale production.



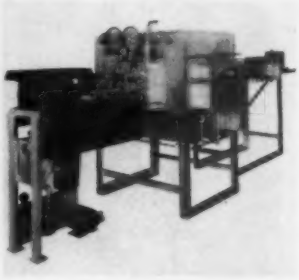
HAYES CONVEYOR FURNACES Types LAC (Straight Through) and BAC (Humpback®—Patented) . . . belt furnaces for continuous, automatic, uniform sintering of brass, bronze or iron compacts up to 2100°F. Available with zone temperature control . . . burn-off sections. For stainless steel work, etc.

HAYES MODEL HT/HV VACUUM FURNACES . . . high vacuum (0.1 micron), high temperature (3000°F plus) units for sintering special refractory metals — titanium, tungsten, zirconium, etc. Cold wall design. Low voltage elements. High-speed heating and cooling cycles.

HAYES TYPE BA-M PUSHER "Pilot Plant" FURNACES . . . inexpensive, for controlled atmospheres, straight-through design, controlled temperature cooling chambers. Manual or automatic operation to 2150°F for sintering powder metal compacts.



HAYES TYPE BA HIGH-PRODUCTION PUSHER FURNACES . . . wide-temperature-range furnaces designed for special sintering applications to 2350°F. Used with varied atmospheres . . . available with automatic, electro-hydraulic pusher system to maintain constant time/temperature cycles for batch or production. Good for stainless steel.



HAYES ATMOSPHERE EQUIPMENT . . . Ammonia Dissociator (shown). Also a complete line of exothermic and endothermic generators, Molecu-dryers for drying protective atmospheres to —100°F D. P.

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Hayes offers you the ***Right*** Furnace . . . and the ***Right*** Atmosphere for specialty or production sintering

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Company.....

Street.....

City..... *State*.....

APPLICATION and EQUIPMENT new literature

42. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it can be used with and parts that can be cleaned. *Globe Steel Abrasive*

43. Acids
Bulletin on naphthenic acids for emulsions and corrosion inhibitors. General properties, specifications. *Sun Oil Co.*

44. Air-Hardening Steel
8-page booklet gives composition, properties, elevated-temperature properties and heat treatment. *Latrobe Steel*

45. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

46. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

47. Alloy Steel
40-page book on applications of heat treated, special alloy steel. *Jones & Laughlin*

48. Alloy Steel Castings
Specifications for T-loy 34 and T-loy 42. Heat treatment and characteristics. *Unitcast Corp.*

49. Aluminum
16-page bulletin lists sizes, weights, lengths of aluminum in rod, bar, plate, sheet. Guide to selection, finishes, mechanical properties. *Ryerson*

50. Aluminum Bronze
8-page bulletin on advantages of aluminum-bronze forming and drawing dies. Properties of alloys used. *Ampco Metal*

51. Aluminum Bronze
8-page booklet on aluminum bronze bearing material which is forgeable, corrosion resistant, lightweight. *Mueller Brass*

52. Aluminum Casting Alloys
8-page bulletin on aluminum casting alloys. Properties; selection of casting method: pig, ingot and billet compositions. *Metals Div., Olin Mathieson Chemical Corp.*

53. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

54. Aluminum Extrusions
Catalog of extrusion dies in stock. *Jarl Extrusions*

55. Ammonia
18-page booklet on ammonia cylinder installations for metal treating. Physical and chemical properties. *Armour*

56. Ammonia Dissociator
12-page bulletin B-53 on ammonia dissociation equipment. Sizes and capacities, testing unit, cost chart. *Drever Co.*

57. Analysis of Nickel Alloys
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloys". *International Nickel*

58. Annealing
Bulletin SC-146 on cycle annealing in atmosphere and direct-fired furnaces. Steels annealed and hardnesses obtained. *Surface Combustion*

59. Anodes
8-page bulletin on copper, brass and bronze anodes for acid-copper plating. *American Brass Co.*

60. Atmosphere Furnaces
New brochure describes various hydrogen atmosphere furnaces for heat treating and brazing stainless steels. Ammonia dissociators for use with this equipment. *American Gas Furnace*

61. Atmospheres
8-page bulletin on heat treating. Data sheets on processes and processing equipment. Also covers annealing, brazing and hardening. *Ferrotherm*

62. Beryllium Copper
New data sheets on three copper beryllium alloys. Analysis, physical constants, mechanical properties, heat treating procedures. *Pennrold Div., Brush Beryllium*

63. Billet Casting
8-page bulletin describing quality control of billet and slab casting of aluminum alloys. *Lobeck Casting*

64. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite Chemical Corp.*

65. Blast Cleaning Barrels
Bulletin No. 705 describes heavy-duty barrels, dimensions, specifications. Information on new equipment. *Pangborn*

66. Brazing
16-page pocket-sized guide to selective fluxing for low-temperature silver brazing. *American Platinum*

67. Brazing
4-page Bulletin No. 81 on hand-torch silver alloy brazing. Models, technique. *Handy and Harman*

68. Carbide Tools
New 40-page Catalog MT-059 gives data and prices for blanks, solid carbide indexable inserts, other tools. *Willey's Carbide Tool Co.*

69. Carbides
New 32-page catalog on line of tungsten carbide tools, tool tips, dies, wear parts. *Adamas Carbide Corp.*

70. Carbon Control
Bulletin C-22 and reprint on Carbontronik for automatic control of carbon potential of atmospheres. *Ipsen*

71. Carbon Products
New 4-page bulletin on carbon and graphite products for the chemical processing and other industries. Pumps, valves, heat exchangers, etc. *National Carbon*

72. Castings
Data on castings of aluminum, magnesium and ductile iron for shock resistance. *Morris Bean & Co.*

73. Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

74. Castings
16-page booklet, "Cast to Outlast Destructive Service", gives latest information and case histories on use of sand, centrifugal and precision investment castings. *International Nickel*

75. Castings
Brochure on plaster mold castings of brass, bronze, aluminum, beryllium copper. *Ohio Precision Castings, Inc.*

76. Ceramics
4-page folder lists industrial products and bulletins describing them. *McDanel Refractory Porcelain Co.*

41. Heat Treatment
The structure and heat treatment of steel are discussed in this 40-page booklet. The iron-carbon diagram is presented and explained as are TTT curves. The structure of carbon steel is described and illustrated with micrographs of steels with different carbon contents and in various conditions. The booklet also tells what happens when steel is annealed, hardened, tempered, martempered, austempered, casehardened, and nitrided. The front cover carries a chart of temper colors. It has a good index. *Sandvik Steel*

77. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

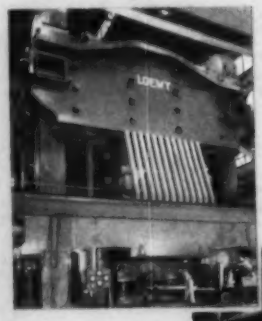
78. Cleaners
Folder on immersion, electrolytic, spray cleaners, phosphate coaters, strippers, drawing compounds, additive agents. *Northwest Chemical*

79. Cleaners
4-page bulletin No. E-1 on five cleaners for power washers, soak tanks, electro-

Hands of the Giants

crack an egg or shape a missile

100,000,000 lbs. of pressure—so delicately controlled that it can be made to crack the shell of an egg. Use the fabulous forces of present day forging skills to crack the barriers of space—weight, strength, high temperatures. Forge the future, today.



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FORT WORTH, TEXAS
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LOS ANGELES, CALIFORNIA

lytic cleaning, emulsion cleaning. *Park Chemical*

80. Coated Pipe
4-page folder on new plastic-coated steel pipe and tubing. How it solves the problem of pipeline corrosion. *Republic Steel*

81. Coatings
4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal Co.*

82. Cold Rolling
Description of advantages of cold rolling of ship propeller shafting. How it is done. *Erie Forge & Steel*

83. Compressors
12-page Bulletin 126-B on application of turbocompressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

84. Controller
New Bulletin F-6314-3 on a self-contained, direct deflection type, indicating controller. *Wheelco Instruments*

85. Controllers
Data on controllers and recorders. *Samuels Sons Iron & Steel Co.*

86. Copper Alloys
36-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside-Alloy Metal*

87. Creep Testers
Article in Metal Digest, V. 4, No. 5, discusses creep testing machines for research and production. *Buehler, Ltd.*

88. Degreaser
Folder on automatic degreaser. Cleaning and solvent cycles described. Features of equipment. *Detrex*

89. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

90. Degreasing
Booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

91. Degreasing
Data sheet 814 on trichlorethylene gives specifications, uses, precautions. *Hooker Chemical*

92. Ductile Irons
New pamphlet on alloys for ductile irons. Table of grades with mechanical property ranges. *Vanadium Corp.*

93. Ductility Testing
Bulletin on simple method of determining ductility of materials before drawing. *Steel City Testing Machines*

94. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

95. Electrodes
Bulletin 810 on removable submerged electrodes. Advantages. *Ajax Electric*

96. Electron Microscope
24-page booklet on use of electron microscope in science and industry. *RCA*

97. Electroplating
Chart gives reference data for gold, rhodium, palladium, platinum, silver, nickel plating. *Technic*

98. Endothermic Atmospheres
16-page reprint on endothermic atmospheres for heat treatment of steel. Effect of temperature on atmosphere. Calculating analysis. *Electric Furnace Co.*

99. Environment Chambers
New folder on temperature, humidity chambers. Models, specifications. *Harris Refrigeration Co.*

100. Environmental Testing
New 12-page Catalog No. 59 on altitude, temperature, sand and dust test chambers, models, specifications. *American Research Corp.*

101. Ferroalloys
Folder on ferrocolumbium additions to steel and high-temperature alloys, analyses and advantages. *Union Carbide Metals*

102. Finishes
Data on production finishes for grinding, polishing and deburring of flat work. Specifications. *Hammond Machinery Builders*

103. Finishing Aluminum
Aluminum finishing manual on cleaning, deburring, etching, deoxidizing, descaling, preparation for welding and anodizing; treatment of corroded stock. *Frederick Gumm Chemical Co.*

104. Flame Hardening
Bulletin tells how flame hardening improves rolls. Chart shows ranges and depth of hardness. *Detroit Flame Hardening*

105. Flow Meters
Bulletin 203 on flow meters for gas used in heat treating. *Waukee Eng'g*

106. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

107. Forgings
Folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

108. Formed Plate
Bulletin on stainless steel elliptical flanged and dished heads. 171 available dies listed. *G. O. Carlson*

109. Formed Shapes
Catalog No. 1053 describing numerous formed shapes made from ferrous and nonferrous metals. *Roll Formed Products*

110. Freezer
Data on chest for use down to −140° F. for production and testing. *Revco*

111. Furnace
4-page bulletin KM-570 on Karbo-Matic automatic furnace for hardening, carbonitriding or carburizing. Operation. Heating elements. *Pacific Scientific*

112. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

113. Furnace Brazing
16-page reprint on brazing of machine parts. Why it is used. Fixtures, joint types, fits, metals and their properties. Typical furnaces used. *General Electric*

114. Furnace Elements
24-page Bulletin H on electric heating elements. Tabular data on physical and electrical specifications for various sizes. *Globar Div., Carborundum*

115. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

'PSC' RADIANT TUBES in
Any Design or Dimension
'Light-Weight' Heat-Treat Units for Every Use
PSC fabricated tubes furnish four substantial advantages: (1) Light-wall construction saves furnace time and fuel. (2) Return bends are of same wall thickness as tubes, promoting uniform flow of gas. (3) Smooth dense walls minimize carbon build-up and burn-out. (4) Up to 100% longer life. In any alloy, size or type, including parabolics. Also sheet-alloy heat-treating retorts and covers, boxes, baskets, fixtures, tubes, etc.
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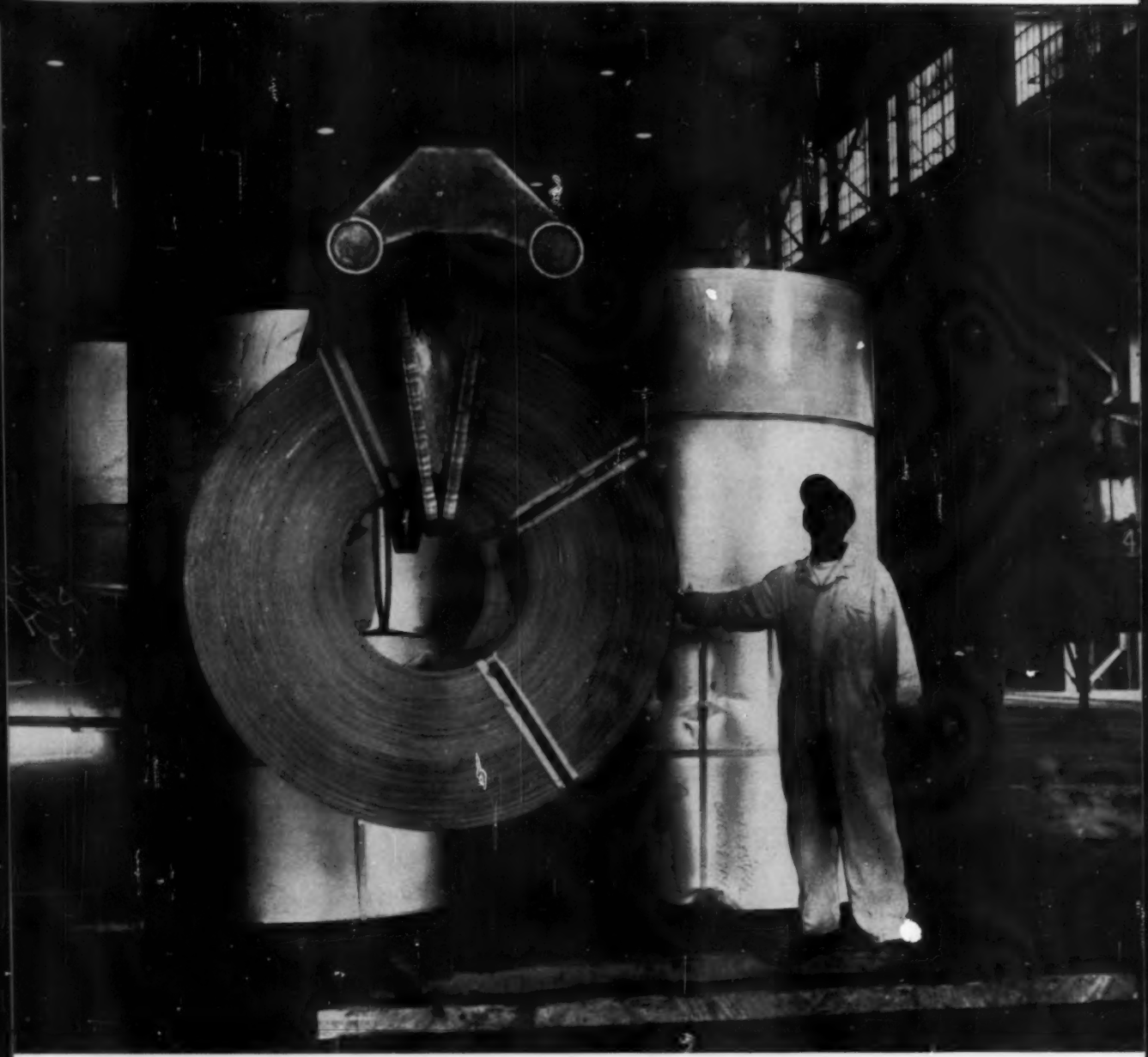

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Emergency? Your steel service center can end it in a hurry with practically any amount, quality, size or shape of steel you may need. No more in-plant steel shortages—no more plant shutdowns—no more lost contracts.

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Call him for any quantity of Weirkote continuous-process zinc-coated sheets, Weirzin electrolytic zinc-coated sheets, hot- or cold-rolled sheets or any type of steel you may need for any type of production job.

WEIRTON STEEL COMPANY

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NATIONAL STEEL CORPORATION

116. Furnaces
List of used furnaces in stock. *Papesch & Kolstad, Inc.*

117. Furnaces
New Bulletin 5710 on conveyor furnaces for operation to 2150° F. Specifications of standard straight through and "humpback" furnaces. *C. I. Hayes*

118. Furnaces
New 6-page Bulletin No. C-80 on soft metal reverberatory furnace. Three models described. Advantages. *Hevi Duty Electric*

119. Furnaces
Catalog on furnaces and ovens for laboratory or production. *K. H. Huppert*

120. Furnaces
12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

121. Furnaces
8-page brochure describing six-electrode arc melting furnaces gives design, advantages, costs. *National Carbon Co.*

122. Furnaces
List of industrial furnaces and equipment in stock. *TherMaTek Co.*

123. Graphite
20-page brochure on significance of graphite as electrodes, anodes, molds, and specialties in electrometallurgy and electrochemistry. *Great Lakes Carbon*

124. Hardening Tool Steels
4-page bulletin on complete line of hydryzing furnaces. Diagrams, specifications and performance data on preheat and high-speed furnaces. *Lindberg Engineering*

125. Hardness Tester
18-page Bulletin DH-325 on Rockwell normal model hardness tester for measuring metals and alloys of all types and shapes. *Wilson Mechanical Instrument*

126. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

127. Hardness Tester
Bulletin A-16 on microreflex hardness testers. Loads to 3000 gr. Zeiss optical system. *Gries Industries, Inc.*

128. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

129. Hardness Tester
Bulletin S-33 on vertical-scale and dial-indicating scleroscopes. How they are calibrated. *Shore Instrument*

130. Hardness Tester
Bulletin TT-59 on tester for measuring standard Rockwell and superficial hardness. *Wilson Mechanical Instrument*

131. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage Industries*

132. Hardness Testing
20-page bulletin on Vickers machine. Description, accessories, advantages. *Riehle Testing Machines*

133. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

134. Heat Treating
Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equipment Exchange*

135. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

136. Heat Treating Fixtures
32-page Catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

137. Heat Treating Fixtures
16-page Catalog M-7 on heat treating baskets and corrosion-resistant-alloy fabrications. *Wiretex Mfg. Co.*

138. Heat Treating Furnaces
New Bulletin No. HT-53 on heat treating furnaces. Construction, design, fuel used. *Carl-Mayer*

139. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

140. Heat Treating Supplies
Data sheets on carburizing, hardening, tempering, nitriding salts, metal cleaning and rust prevention materials. *Heatbath*

141. Heating
Bulletin on Heat-O-Coil resistance wire for preheating and stress relieving. *Arcos Corp.*

142. High-Strength Steel
Data sheet and 16-page folder on Vasco-Jet 1000, 5% chromium air-hardening steel. Mechanical properties, fatigue strength, heat treatment and surface properties. *Vanadium-Alloys Steel Co.*

BLASTRITE
SHOT and GRIT
A complete range of sizes, standard or made-to-order.
CHILLED CAST IRON SHOT & GRIT
For tough cleaning jobs or surface finishing of heat-treated parts.
STEEL SHOT & GRIT (Hardened and Drawn Cast Steel)
Ideal for cleaning and peening where carry-out and abrasive loss are minimized.
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HI-ALLOY "A" IRON SHOT & GRIT
Hi-strength reduces fracturing due to impact.
MALLEABLE SHOT & GRIT
Best for impact type cleaning machines.
CUT STEEL WIRE SHOT (Hard Drawn Cut Steel Wire)
Extensively used in peening springs and other metal parts.
Catalog No. AB-53 will give you further details on these stocked items, as well as those manufactured as ordered.

Free cost system installed

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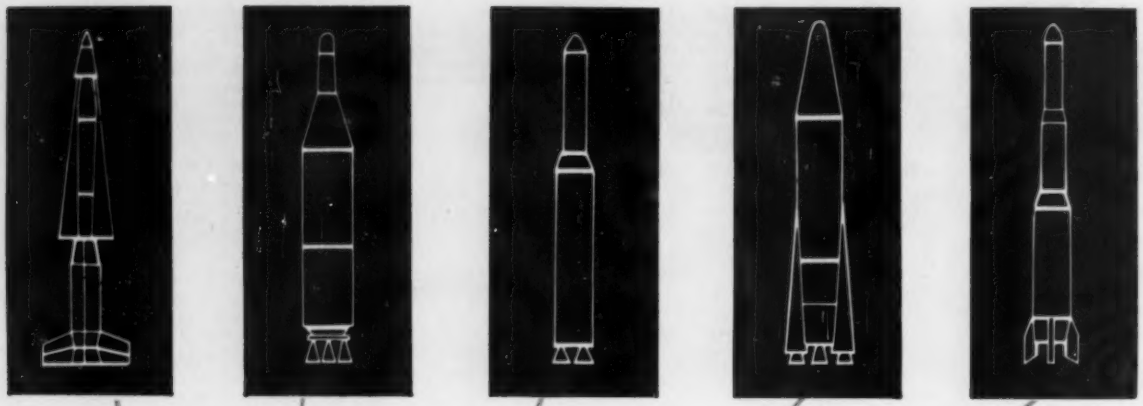
Phone: Lyceum 2-2816 Teletype: Springville NY 502
Manufacturers of BLASTRITE quality abrasives



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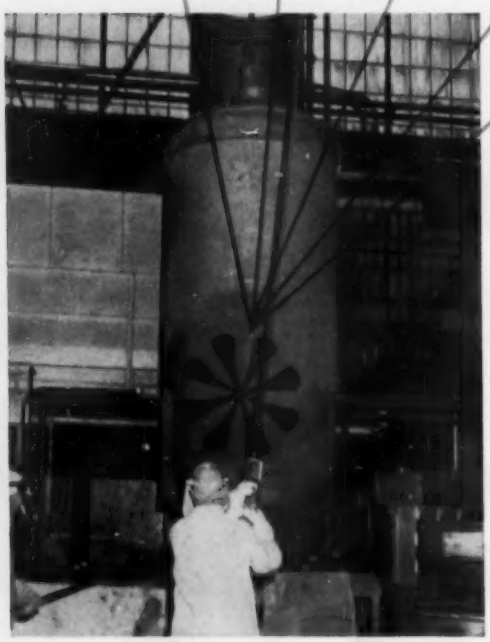
HOUGHTON MAR-TEMPERING SALTS



In four of the largest salt bath quenching operations in the U. S., Houghton Mar-Temp Salts are used to quench vital components and flight chambers of a wide variety of missiles and rockets.

The precision quenching possible with Houghton Mar-Temp Salts prevents distortion and cracking, yet insures the strength and hardening accuracy necessary for precise performance and reliability. Missile metallurgists also prefer Mar-Temp quenching for greater cleanliness and to eliminate safety equipment needed in oil quenching.

Houghton's care in compounding salts and Houghton heat treating "Know-How" were major factors in the selection of Mar-Temp Salts for such important defense projects. You can get the same expert help and high-quality materials for your own heat treating processes by a call or letter to E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.

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Ready to give you on-the-job service

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HARRIS HELPS...

HOOVER

ASSURE DIMENSIONAL STABILITY OF TOOLS AND GAGES

Ernest U. Day, Foreman of Hoover's Tool Department, applauds the performance of their Harris 6 cu. ft. heavy-duty chilling machine for achieving "more accuracy and more stability", the two prime objectives of tool and gage fabrication.

A Harris Chilling Machine during the past two years has solved the serious problem of achieving dimensional stability in steels for gages in the Tool Department of the famous Hoover Company, North Canton, Ohio, leading manufacturer of vacuum cleaners. Chilling has also proved a quicker and more positive method for shrink-fits on die assemblies.

Super-chilling at –130° to –150° F and tempering will achieve 100% transformation of austenite to martensite in water and oil-hardening steels, ideally suited for gages but slightly sluggish to austenitic decomposition.

A super-chill also increases Rockwell hardness by several points in high-carbon, high-chrome steels, needed for dies but also sluggish in transformation.

LEARN HOW CHILLING CAN IMPROVE YOUR TOOLS AND PRODUCTS . . . AT LESS COST. WRITE TODAY OR SUBMIT SAMPLE PARTS FOR TEST PROCESSING. NO OBLIGATION.

HARRIS REFRIGERATION CO.

308 River St., Cambridge 39, Mass.

Specialists in refrigeration engineering, manufacturing, and service since 1934.

143. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys*

144. High-Temperature Alloys
20-page booklet on nine alloys for elevated temperature service. Data sheets cover analysis, physical constants, mechanical properties, heat treatment, workability, machinability, welding, corrosion resistance. *Carpenter Steel*

145. High-Temperature Lubrication
Bulletin 423 on colloidal graphite and molybdenum disulfide dispersions and their use for high-temperature lubrication. Case histories. *Acheson Colloids*

146. High-Tensile Steel
8-page bulletin on properteis and composition of N-A-X high-tensile steel. Examples of resistance to impact, fatigue, abrasion and corrosion. *Great Lakes Steel*

147. High-Vacuum Pump
4-page bulletin on small, air-cooled, compound, high-vacuum pumps. *Kinney Mfg.*

148. Identifying Tool Steels
Folder describing new spark testing standard for identification of tool steels and surface conditions. *GLD Products Co.*

149. Induction Heaters
8-page bulletin EH 57-6 on electronic induction heaters. Specifications, basic components, guide to brazing and soldering and frequency selection chart are included. *Magnethermic*

150. Induction Heating
Bulletin on Multiductor frequency conversion unit. Applications, heating rates. *Ajax Electrothermic Corp.*

151. Induction Heating
Induction Heating News No. IHN-7 describes applications of induction heat in heat treating of metals. *Induction Heating Corp.*

152. Induction Heating
Need for ground detectors on high frequency induction furnace discussed in Inducto Metal Melting Newsletter, No. 5. *Inductotherm*

153. Induction Heating
60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

154. Industrial Furnaces
Folder on batch, automatic, continuous gas, electric and oil furnaces. Selection chart shows which operations may be performed in which type of furnace. *Sunbeam Equipment Corp.*

155. Inspection
New 4-page Bulletin F-9 on magnetic method and equipment for locating invisible defects in ferrous metal parts and assemblies. *Ferro Machine and Tool*

156. Inspection
Bulletin on Spotcheck dye-penetrant inspection. Advantages, prices. *Magnaflux Corp.*

157. Inspection
Data on ultrasonic inspection and thickness measurement service in field or laboratory. *Sperry Products*

158. Insulation
16-page Bulletin R-2-H on insulating firebrick. Properties of six grades and applications of each. Design of arches and circular linings. *Refractories Div., B. & W.*

159. Investment Casting
"Pointing the Way" presents seven case histories on advantages of investment castings. *Engineered Precision Casting*

(Continued on page 48-A)

STRAITS TIN REPORT

News of developments in the production and uses of tin

MALAYAN TIN BUREAU

Zircalloy 2 – containing 1.5% or more tin – was the cladding material used for the nuclear power unit which carried the submarine Nautilus across the North Pole. Zirconium alone couldn't do it. Addition of small quantities of tin strengthened the zirconium and reduced the variable effect of impurities. It also had a favorable effect on its corrosion resistance. This discovery led to development of Zircalloys containing 0.5 to 5% tin.

Factory fresh hosiery is now available to American consumers in tin cans. The manufacturers claim canning nylons reduces pilferage and handling costs, lets the lady select her nylons factory fresh from her grocer's shelf.

Foreign car manufacturers are capitalizing on latest developments in tin applications. Directional signals, subject to continuous wear and hard weather conditions, are electroplated with a tin-zinc coating. A tin-nickel electrodeposit shows good potential as a bright tarnish-resistant coating for automotive trim, bumpers and accessories. A tin-bronze coating of up to 12% tin and a tin-nickel coating of two-thirds tin are proving excellent undercoatings for chromium.

Write today for more data on these items or for a free subscription to TIN NEWS—a monthly bulletin on tin supply, prices and new uses.

The Malayan Tin Bureau
Dept. 25G, 1028 Connecticut Ave., Washington 6, D.C.

COMPLETING THE PICTURE . . .

Nuclear Systems Economical, Portable Radiography Machines

MODEL 52 MULTITRON

At Convair, San Diego, steel parts for air or space craft must be absolutely flawless to take their designed loads. Quick, positive inspections of these parts are made by a Nuclear Systems Model 52 Multitron with a cobalt 60 source. The unit can be wheeled about at will . . . wherever radiographic inspection is needed.

Like Convair, companies all over the country are making sure of quality, saving time and money by inspecting with radiography machines from Nuclear Systems.

If you have an inspection problem, Nuclear Systems has a safe, portable, economical radiography machine to suit your needs. For full information, contact Dept. M-7 at one of our sales offices. Also . . . inquire about Nuclear Systems' regularly scheduled three-day Radiation Health Physics Course —an approved AEC licensing aid.

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A DIVISION OF THE BUDD COMPANY, Philadelphia 32, Pa.

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Budd

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

now...Lehigh H leads the field in machinability

As the result of its special annealed structure, developed and tested over a period of several years, Bethlehem's Lehigh H tool steel (AISI Type D-2) now leads the field in machinability among the high-carbon, high-chrome tool steels sold today. In impartial studies, the machinability of Lehigh H has been proved outstanding as a most economical grade for a wide range of difficult applications.

In addition to its better machinability, Lehigh H now has improved wear-resistance, because its vanadium content has been increased to 1 pct. Other important advantages of Lehigh H: improved carbide distribution and increased center density, based on U. S. Patent No. 2,809,109, issued to Bethlehem. Its uniform structure makes possible a better response to heat-treatment, and results in maximum service life for tools and dies, even in the most severe service.

Lehigh H is the D-2 type of air-hardening high-carbon, high-chromium tool steel, which is well known for minimum dimensional change in heat-treatment. For tops in machinability, and for all-around dependability and economy, be sure to order the new improved Lehigh H from your Bethlehem tool steel distributor.

HOW ELECTRONIC TUBE CRITICAL HEATING *WITH LOW MAINTENANCE*

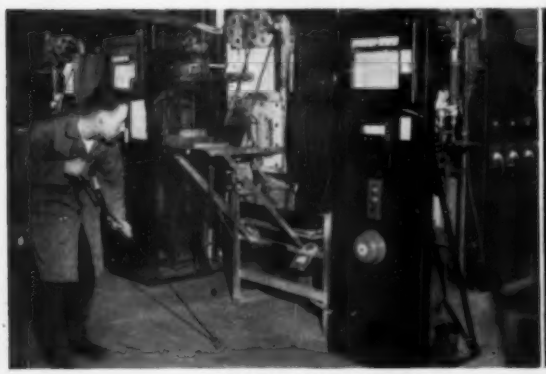
TWO OF THE ELECTRIC FURNACES, manufactured by C. I. Hayes, Inc., 800 Wellington Avenue, Cranston, R. I., are shown above. GLOBAR heating elements are used to insure the accurate control and clean heat required in critical heat treating and brazing operations.

PLANT SOLVES PROBLEM... *COSTS*

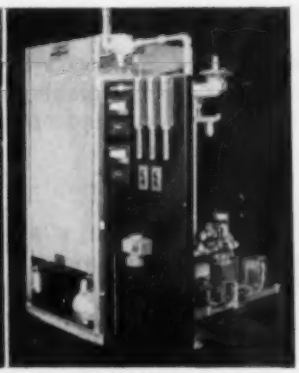
Westinghouse Electric Corporation, Electronic Tube Division, uses electric furnaces with controlled atmosphere generators *(ammonia dissociators)*... both equipped with GLOBAR® electric heating elements

Hydrogen heat treating and brazing of critical electronic tube components in the 600 C—1200 C range are carried out in one Hayes 5" x 7" Pusher and two 12" belt conveyor electric furnaces at the Westinghouse Power Tube Manufacturing Department, Horseheads, N. Y. The usual materials used are copper, steel and nickel of exacting specifications which must be carefully maintained. The work produced by all three furnaces is bright and clean. In addition, the pusher furnace can be used with a retort box under high gas flow to produce annealed magnetic alloy parts. Controlled atmospheres for all furnaces are provided by Hayes Generators.

GLOBAR silicon carbide electric heating elements are used in both the furnaces and an atmosphere generator. "We have found from experience over several years that these furnaces equipped with GLOBAR elements do a fine job and require little maintenance," says Westinghouse. "They perform satisfactorily in maintaining a range of critical temperatures."



ATMOSPHERE GENERATORS (ammonia dissociators), used in conjunction with the furnaces, are also a Hayes product. Here again, GLOBAR silicon carbide elements are used to supply closely controlled heat.



LATEST TYPE "IGL" Hayes Protective Atmosphere Generator, using the new GLOBAR Delta elements. Features include easier removal of catalyst, improved instrument layout and precise acting carburetor for control of air-gas ratio.

The ECONOMIC advantages of electric heat:

There are many reasons why GLOBAR Delta silicon carbide elements are economical as well as dependable, clean, safe, and quiet. There is no fire or explosion hazard, and exhaust and fuel storage facilities—and costs—are unnecessary.

Only with electric heat can heating cycles be precisely duplicated and temperatures accurately controlled, independent of the atmosphere. Product quality is improved and rejects sharply reduced. Electric furnaces and kilns are compact and space-saving. They can be located in the production line, thereby accelerating production and reducing costs per unit of product.

The investigation of an electric heating application should include more than the comparison of BTU and electricity costs. Lower furnace maintenance and operating cost, plus full utility of BTU input, will frequently more than offset a fuel cost differential.

Installation of Delta elements is simple, and element replacement is accomplished quickly without cooling the furnace or interfering with production.

Typical applications for GLOBAR Delta elements include furnaces and kilns for: heat treating, forging, sintering, brazing, annealing, melting, assaying, roasting, laboratory and research: and ceramic firing of ferrites, titanates, steatities, refractories, electrical insulators, grinding wheels, whiteware, pottery and tile.

Find out how your operation could profit by using GLOBAR Delta silicon carbide electric heating elements. Your furnace builder can supply you with full details. The Carborundum Company, Refractories Division, Globar Plant, Dept. MP-79, Niagara Falls, New York.

CARBORUNDUM

Registered Trade Mark

AUGUST—Selected supplier of anhydrous ammonia . . . assuming that service included technical advice "during use".

LATER—Ammonia system installed without supervision . . . not tested by supplier . . . some parts not designed for ammonia use.

STILL LATER—Had improper atmosphere mixture . . . undesirable case properties . . . sooting and added handling of "finished" parts.

TOO LATE—Too many rejects . . . supplier unable to aid on application. Labor, material and operating costs up . . . profits down.

BE TROUBLE-FREE! Buy your ammonia from Armour. And receive expert technical service—whenever you need it —at no added cost.

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Serving industry for more than half a century with the purest ammonia money can buy.

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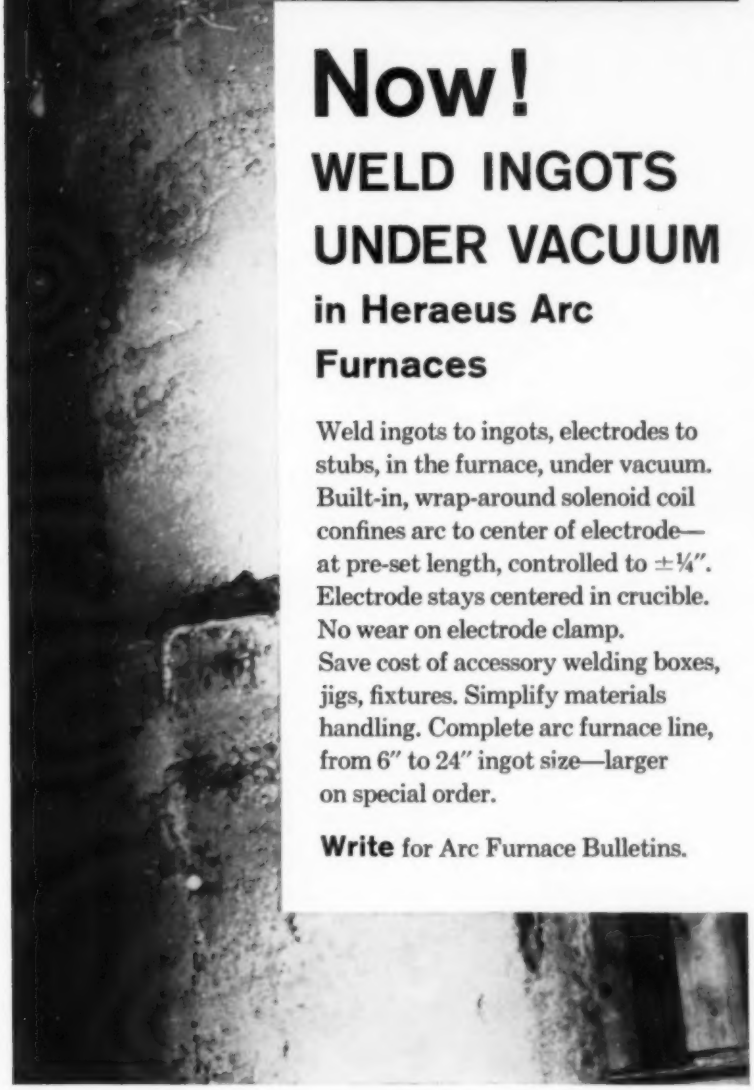
WELD INGOTS UNDER VACUUM

in Heraeus Arc Furnaces

Weld ingots to ingots, electrodes to stubs, in the furnace, under vacuum. Built-in, wrap-around solenoid coil confines arc to center of electrode—at pre-set length, controlled to ±¼". Electrode stays centered in crucible. No wear on electrode clamp. Save cost of accessory welding boxes, jigs, fixtures. Simplify materials handling. Complete arc furnace line, from 6" to 24" ingot size—larger on special order.

Write for Arc Furnace Bulletins.



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Rochester Division, Rochester 3, N.Y.

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48-B

THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments

control flexibility adds value to multi-purpose furnace

Hevi-Duty furnace for toolroom applications. Gasketed door sealing against alloy muffle permits use of controlled atmospheres. Temperatures up to 1850° F are controlled by Wheelco 290 Series instrument.

Where a multi-purpose furnace is needed for toolroom and laboratory operations up to 1850° F, this "Treet-All" furnace built by Hevi-Duty Electric Company, Milwaukee, meets the job requirements at minimum equipment cost. A Wheelco 290 Series indicating controller is an essential element of the standard control unit located in a steel enclosure directly below the furnace proper. It provides the flexibility and control accuracy required for a broad range of operations.

Because of Wheelco's record for accuracy and dependability, Hevi-Duty also uses 290 Series instruments in the tempering furnace and atmosphere generator that complete this toolroom combination. Contact your nearby Wheelco field engineer to learn how to benefit from quality instrumentation on your jobs, or write Wheelco direct for Bulletin F-5358-1 describing 290 Series instruments.

BARBER-COLMAN COMPANY

Dept. S, 1518 Rock Street, Rockford, Illinois

BARBER-COLMAN of CANADA, Ltd., Dept. J, Toronto, Canada

Industrial Instruments • Automatic Controls • Air Distribution Products • Aircraft Controls • Electrical Components • Small Motors • Overdoors and Operators Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

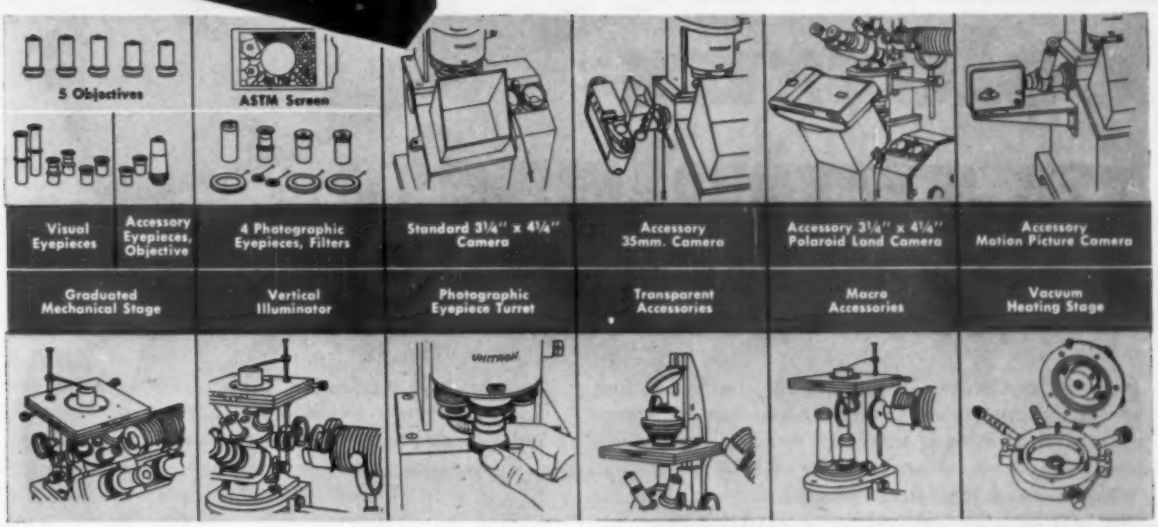
In METALLOGRAPHS...

the trend is to UNITRON!

What do you look for when choosing a metallograph? All of the popular makes are precision instruments, are reasonably versatile and, to a varying degree, are easy to operate. But, except for UNITRON, all have the bulk of an office desk or optical bench and are tagged with a price that puts a substantial dent in the laboratory budget. UNITRON, and only UNITRON, offers a completely equipped metallograph in a compact and self-contained unit, taking only 9" x 12" of table space, which duplicates the performance of large cumbersome instruments — and at a price which is hardly more than the usual cost of a conventional metallurgical microscope.

Unlike the case with most metallographs, an adding machine is not required to compute its cost. Coated optics supplied as standard equipment include 5 objectives, 4 photographic eyepieces and 3 pairs of visual eyepieces. These give a magnification range of 25X-2000X. Also included in the purchase price are the built-in 3¼" x 4¼" camera and viewing screen; high-intensity illuminator for vertical, oblique, and transmitted light; variable transformer with both voltmeter and ammeter; accessories for transparent specimens; polarizing apparatus; filters; film holders; stage clips; cabinets etc. Optional extra accessories include Polaroid Land, 35mm. and movie camera attachments; low power (5X-40X) objectives for macro work; vacuum heating stage for temperatures to 1100°C and long working-distance 40X objective; ASTM Austenite grain size viewing screen and eyepieces; filar micrometer eyepiece; and additional optics.

Such a combination of features, versatility, convenience, and value is indeed unique with UNITRON. Little wonder then, that more and more laboratories are choosing UNITRON . . . from the large organization adding another metallograph to its equipment, to the small company buying an instrument for the first time.



FREE 10 DAY TRIAL

UNITRON's Metallograph and Universal Camera Microscope Model BU-11 with binocular eyepiece; objectives: M5X, M10X, M40X, 40X for transmitted light, 100X oil immersion; paired visual eyepieces: R5X, Ke10X Micrometer, Ke15X; photo eyepieces: 10X, 15X, 20X, Micrometer; etc., as described above.

$1379 f.o.b. Boston

Monocular Model U-11 **$1195**

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INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
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Please rush UNITRON's Microscope Catalog 2-S

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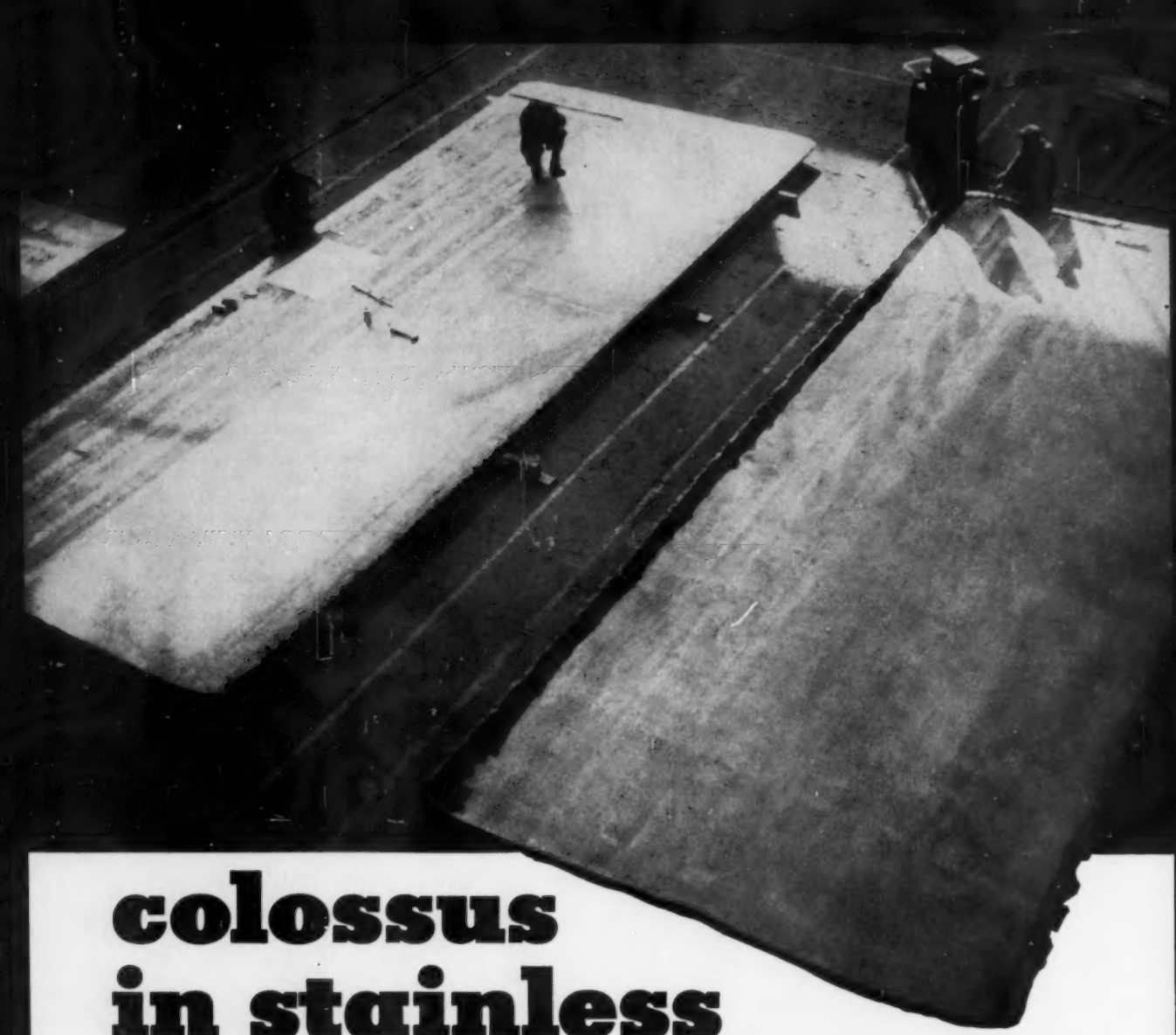

colossus in stainless

...world's largest stainless steel plates ready for processing at Carlson

SOMETIMES Carlson service is a cooperative venture that gets practically impossible jobs done. The processing and finishing of these, the world's largest stainless steel plates, is an example of such teamwork.

As this was a "first time" job, the most careful planning and coordination had to be exercised. Oversize ingot molds and a 70-ton capacity furnace had to be used. It took the country's largest plate mill to roll the ingots to slabs, the slabs to plates. The finished plates, cut-to-shape by Carlson specialists, met every customer requirement.

These huge plates, of Type 304 stainless steel, were made to Specification A-240 Grade S (ASTM A240-T). Each plate weighed over 49,000 pounds; one measured 461" x 179" x 2"; the other 451" x 184" x 2". Destined for a nuclear application, these plates were flame-cut and abrasive-cut to make two half-circles. The entire order totaled nearly 100,000 pounds.

Cooperation made this "colossus" a success—cooperation under the knowing eyes of Carlson specialists. This same team is ready to work on your order. We invite you to write, wire or phone for further information.

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Stainless Steels Exclusively

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District Sales Offices in Principal Cities

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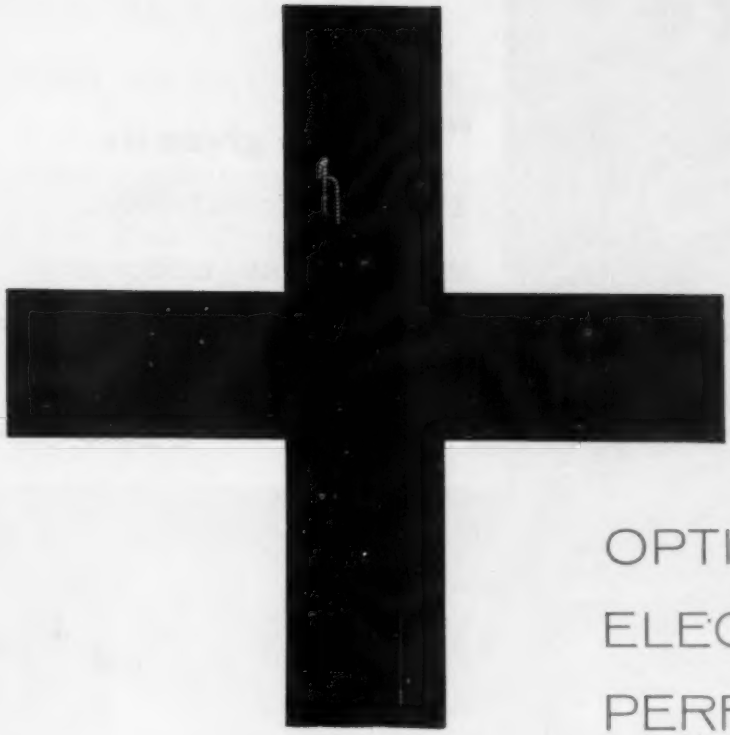

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. . keeps electric furnace steel costs down.

The flawless machining of GLC electrode sockets and Unitrode® nipples, to the most exacting tolerances, raises electrode column efficiency to new highs through the sharp reduction in joint resistance. Let comparisons prove this to you!

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Lengths of oil well casing are in production at the A. O. Smith Corporation in Milwaukee. They are being stress relieved in a gas furnace.

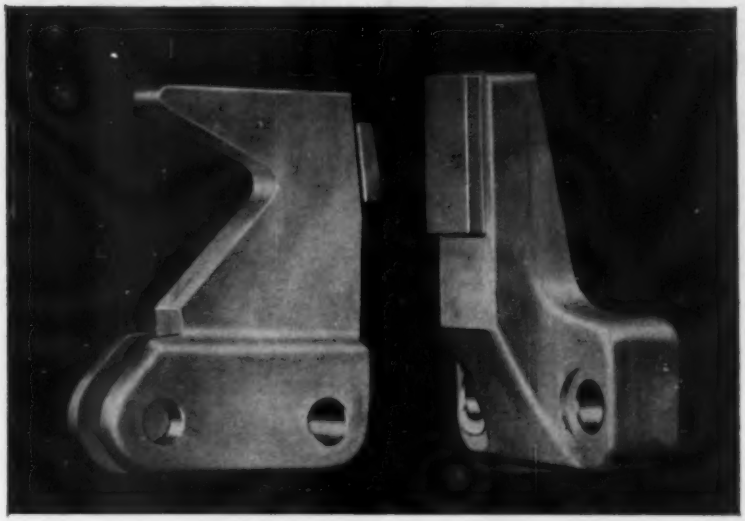
Gas has proved best on A. O. Smith's production line because of its cleanliness, controllability, speed and economy. Gas gives nearly 50% reduction in cost over their previous fuel, and carbon spots have been eliminated. There are three pre-heat furnaces that heat the pipe to 1650°-1750°, depending on the size of pipe. Three re-heat furnaces bring the temperature back up before quenching.

A. O. Smith also produces auto frames, pressure vessels, glass lined farm storage units and tanks, glass-lined gas water heaters and furnaces. Throughout their operations, gas is installed as an integral, indispensable part of their production lines.

For information on how gas can help you in your production operations, call your gas company's industrial specialist. He'll be glad to discuss the economies and superior results you get with modern gas industrial equipment. *American Gas Association.*

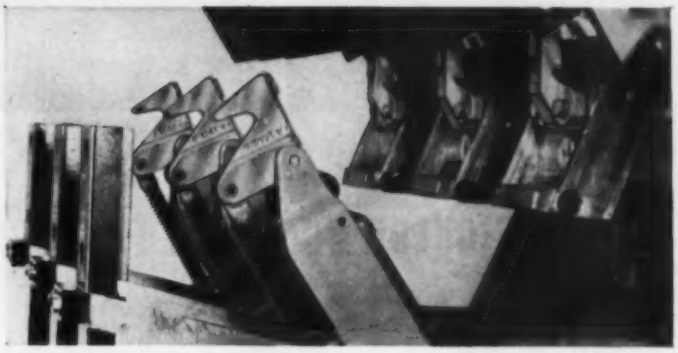
TWICE-WROUGHT METAL

of die-pressed forgings helps Federal Pacific make new air circuit breakers more rugged—cuts machining costs in half

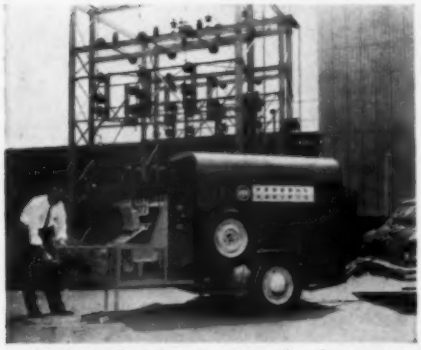


In its new Type DST magnetic air circuit breaker line, Federal Pacific Electric Company, Newark, N. J., builds in dependable operation and long life with parts of outstanding mechanical and adequate electrical properties.

Typical of this attention to detail are the arcing contacts (left). Similar parts previously used had been castings or built-up assemblies. Now the contact bodies are Anaconda Forging Brass-250 die-pressed forgings. The twice-wrought metal is denser, stronger, withstands mechanical shock better—reducing the fatigue factor and producing longer service life. The contacts also have higher conductivity. And best of all, their consistent dimensional accuracy and smooth finish cut machining costs in half.



RIGHT: Movable arcing contact assemblies at the left and the stationary arcing contact assemblies at the right in a 5-kv Federal Pacific Type DST air circuit breaker. They have a momentary current-carrying capacity of 60,000 amperes. Contact tips of tungsten alloy are silver-soldered to the forgings. These are two of several areas where Federal Pacific uses the superior physical properties of Anaconda die-pressed forgings to help provide dependable operation and long service life in its line of metal-clad switchgear.



Federal Pacific takes its circuit breakers out to industrial and electric utility customers. Here a representative sets up a demonstration of a 5-kv, 1,200-amp breaker in the field.

IT IS often easier than you think to achieve high quality and performance while simplifying fabrication and cutting over-all costs. American Brass technical specialists are constantly working with designers, production engineers and buyers, helping them meet their joint requirements—through the use of such Anaconda mill products as die-pressed forgings, extruded shapes, special-shape tubes. For this kind of practical help, see your American Brass representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Toronto 14, Ontario. 3544

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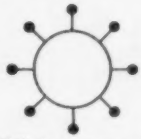

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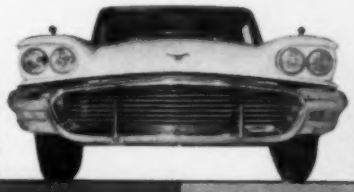

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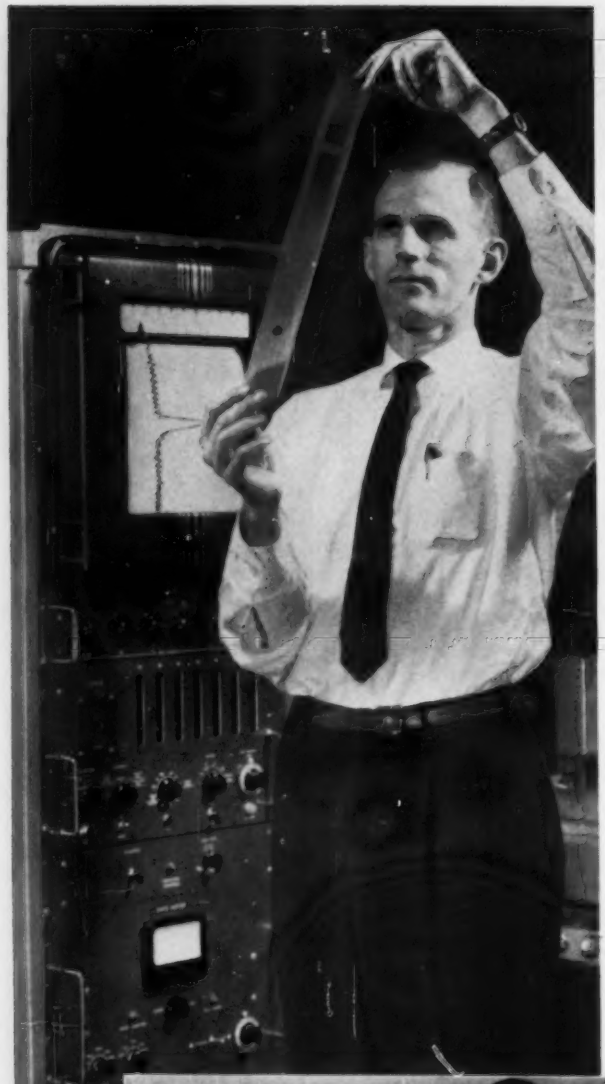

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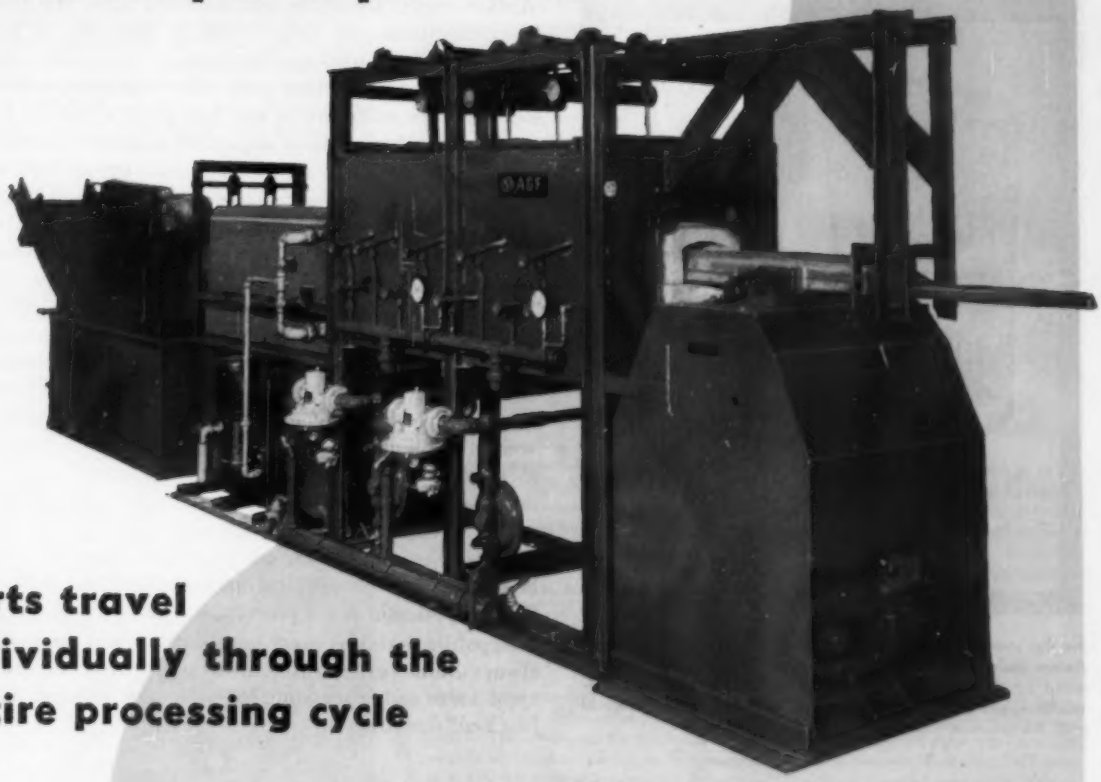

Parts travel individually through the entire processing cycle

This new Shaker Hearth employs an alloy muffle which incorporates a purging, heating and water-jacketed cooling section, and seals into an automatic conveyorized oil tank.

Among the many operational advantages of this new line of Reciprocating Furnaces, are the maintenance of —80° to —90° F. dew points . . . complete atmosphere uniformity throughout the processing cycle . . . and a very low consumption of atmosphere gas . . . Batch purging, heating and cooling are eliminated . . . and the parts may be observed throughout the entire processing cycle through openings in the charge and discharge ends of the muffle.

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FUNCTIONAL STAINLESS STEEL IS CORROSION-RESISTANT, STRONG, WEIGHT-SAVING, READILY FORMED

The high strength-to-weight ratio of stainless steel permits the use of slimmer channels and frames in passenger car and truck sash. Protected by stainless, glass breakage is less likely. Strength, dent-resistance, and corrosion-resistance make stainless ideal for radiator grills. Manufacturer—Excel Corporation, Elkhart, Indiana.

Always right, always bright stainless steel, the optimum metal for trim and brightwork, is showing up in ever-increasing functional applications.

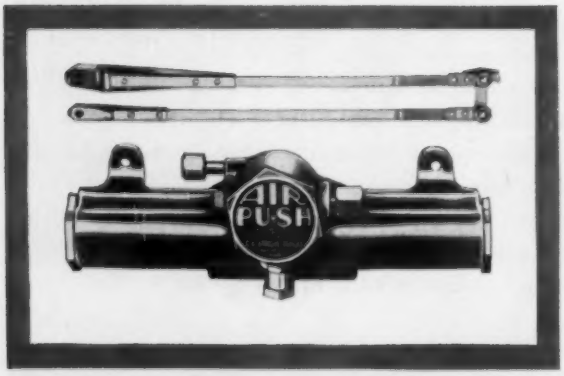
The reason? Stainless steel offers automotive part and equipment manufacturers and designers a combination of qualities unobtainable in any other commercial metal.

Stainless steel parts are tough and strong, yet lightweight. They offer outstanding resistance to heat, wear, and abrasion. They stubbornly resist rust and corrosion. Maintain their great strength through extremes of heat and cold.

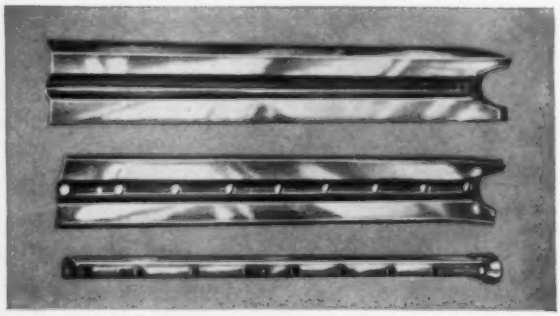
Stainless is readily formed into desired shapes and designs on present equipment with little or no change in procedure and often at lower ultimate cost. Conventional welding techniques, currently in use on production operations, permit the combining of strong, lightweight stainless to carbon steel panels. The result is an over-all reduction in weight without loss of strength or safety, and a structural member that is both functional and decorative.

The functional stainless steel parts and equipment illustrated on these pages represent only a few of many current applications. Others include: mufflers, head gaskets, exhaust manifold butterfly valves, fasteners, heat exchangers. Future applications are practically unlimited.

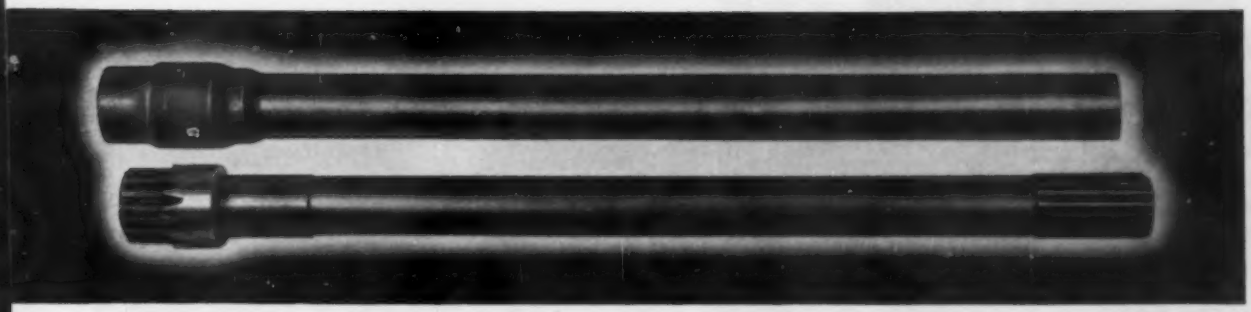
Republic Stainless Steel metallurgists and engineers are always available for consultation on development, selection, application and processing. No obligation for their services. Just mail the coupon.



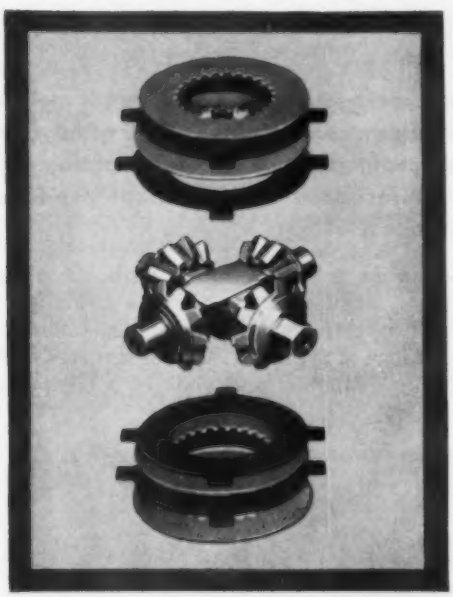
Stainless steel makes an important contribution to the safe operation and maintenance of windshield wipers. Stainless steel's strength assures resistance to breakage or distortion. Light, strong design reduces dead weight that the wiper motor must move. Elasticity of stainless gives the blade the proper pressure on the glass. The wiper arms are protected against the slow and insidious weakening effects of corrosion. Manufacturer—Sprague Devices, Inc., Michigan City, Indiana.



Formability, corrosion-resistance, and cost were prime factors in switching to stainless steel from brass in this engine water distribution tube. Stainless was easily fabricated on existing tools. It took the constant flow of hot water and anti-freeze chemicals in stride. The greater strength of stainless virtually eliminated loss from bent or damaged tubes. Photo sequence shows fabricating operations: (1) Blank of .010" stainless strip after initial drawing and embossing, (2) Same blank after piercing of water outlet holes trimming of flanges, (3) Completed tube after roll-forming and lock seaming. Produced by Pontiac Motor Division of General Motors Corporation.



NEW FABRICATING PROCESS MEANS ECONOMY. Ford Tractor power take-off countershafts cost less to produce using Republic Die-Form blanks, as compared with previous materials. Blank is shown at top, completed shaft below. Die-Form is a new method of cold forming hot rolled carbon, alloy, or stainless steel bars into multi-diameter blanks ready for final machining. Because Die-Form blanks closely approximate the completed part, scrap losses are negligible. Improved machinability permits savings through use of higher speeds and feeds. Mail coupon for complete facts.



NEW HIGH STRENGTH POWDER, TYPE HS 6460, opens the way for new applications using sinterings for highly stressed parts. Type HS 6460 can be used with existing operating equipment. It provides a minimum tensile strength of 60,000 psi at 6.4 density as sintered, 100,000 psi heat treated. Type HS 6460 maintains its dimensional characteristics after sintering—less than .004 inches per inch shrinkage from die size at 6.4 density. Available in production quantities up to and including 12 tons, or in multiples thereof. Mail coupon for technical data sheet.

SUPER TOUGHNESS AND STRENGTH at critical points are provided by Republic Alloy Steels in the Powr-Lok Differential developed by the Dana Corporation, Toledo, Ohio. Dana engineers have reduced the possibility of mechanical breakdown in clutch rings and side gears to an absolute minimum by forging these parts from Republic Hot Rolled 8615 Alloy Bars. This fine steel offers superior strength and toughness to withstand torque, fatigue, shock, and stress. Uniform response to heat treatment gives the parts hard surfaces around tough cores providing maximum resistance to abrasion, friction, and wear. An exceptionally high strength-to-weight ratio permits the designing of thinner sections to save weight and hold down size. Send coupon for full facts.

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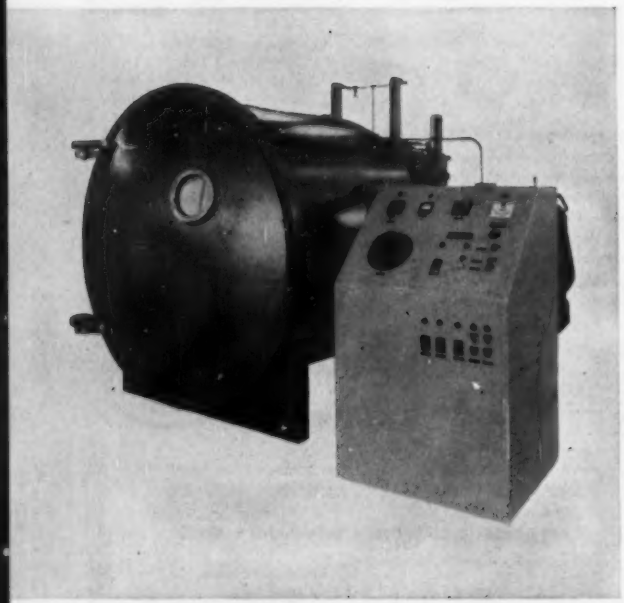
Uranium melting on a production basis is easily accomplished with this Stokes induction melting furnace. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of poured materials. It is typical of the inherent flexibility of Stokes equipment which meets the demands of specific processing techniques and requirements.

Profit from

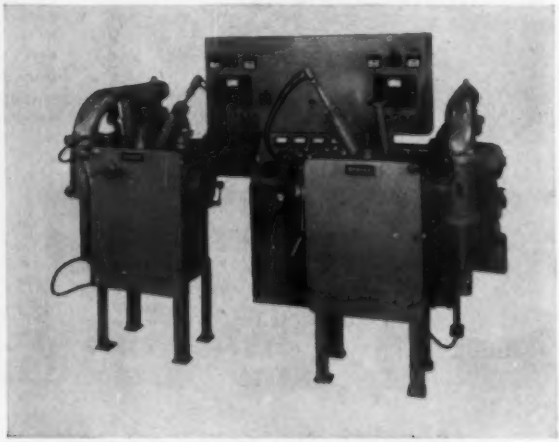
...with STOKES

With a quickening pace, Stokes vacuum metallurgical equipment is helping industry find new paths to profit through a combination of intensified research and practical production techniques.

Stokes design experience coupled with complete manufacturing facilities makes possible meaningful technological developments in vacuum metallurgy. A complete range of types and sizes of furnaces and metallizers are available, and you get a complete



New applications for metallizing are developing at a rapid pace. Vacuum coating with corrosion resistant cadmium and aluminum is playing an increasingly greater role in production of critical, high tensile strength aircraft parts. Lustrous layers of aluminum, vacuum applied on inexpensive metals, can produce quality outdoor lighting reflectors at lower costs. Electronic components, such as resistors, utilize vacuum deposited metallic coatings to achieve weight and space savings with improved reliability, stability and uniformity of temperature coefficient.



High order investigations in vacuum melting are made possible with this Stokes 50-lb. vacuum furnace. A production unit as well, it is available in single or dual chambers plus a variety of automatic types. The unit is shipped as a completely assembled, ready-to-operate system to save customers time and money.

Technological Breakthroughs

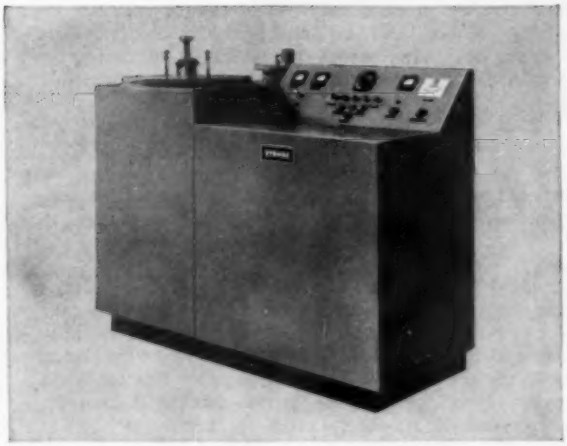
Vacuum Metallurgical Equipment

system . . . Stokes becomes a single source of responsibility for performance and reliability. The same unique design and fabrication ability is easily and economically applied to many types of special metallurgical equipment to meet specific customer requirements.

Stokes offers advantages that take the guesswork out of operations and brighten your profit picture. For example, Stokes can deliver a complete turnkey installation—erected, tested and delivered "in operation." And stocked components mean faster delivery, fewer costly holdups. What's more, a Stokes system offers optimum efficiency, operating simplicity and low maintenance.

Standard Stokes Vacuum Furnaces range from small, compact R&D models to full production size systems. They're available for melting, refining, casting, heat-treating, sintering, brazing and degassing. Custom-designed units are available to meet unique requirements. Metallizers are available in a wide range of sizes for a variety of applications. And Stokes complete service is yours both before and after the sale, whenever you require it.

Take full advantage of Stokes advanced vacuum technology. The Stokes Engineering Advisory Service will assist you in planning and designing an installation that will best serve your exact requirements. Why not contact Stokes—today.



Special sintering applications and solid-state processing technique investigations are handled by new Stokes cold wall furnace. It reaches further into the high temperature ranges . . . depending on application, up to 2500° C at sub-micron pressures. For use with refractory as well as more common base metals and alloys, the furnace is ideally suited to both research and production services.

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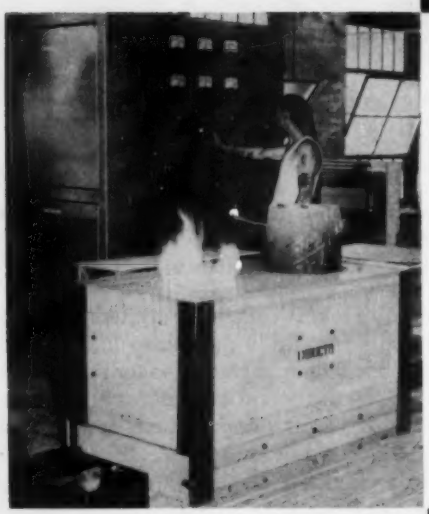

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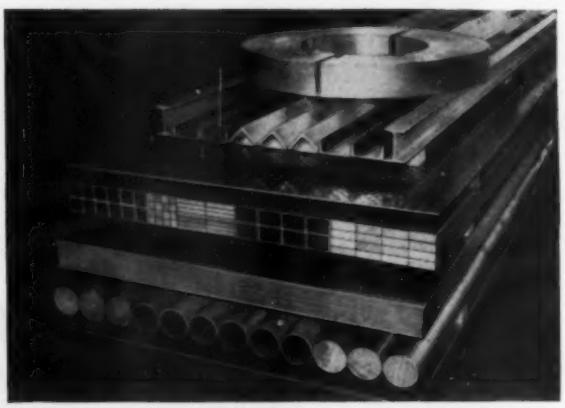

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Metal Progress
Vol. 76, No. 1 July 1959

Forging and the Space Age

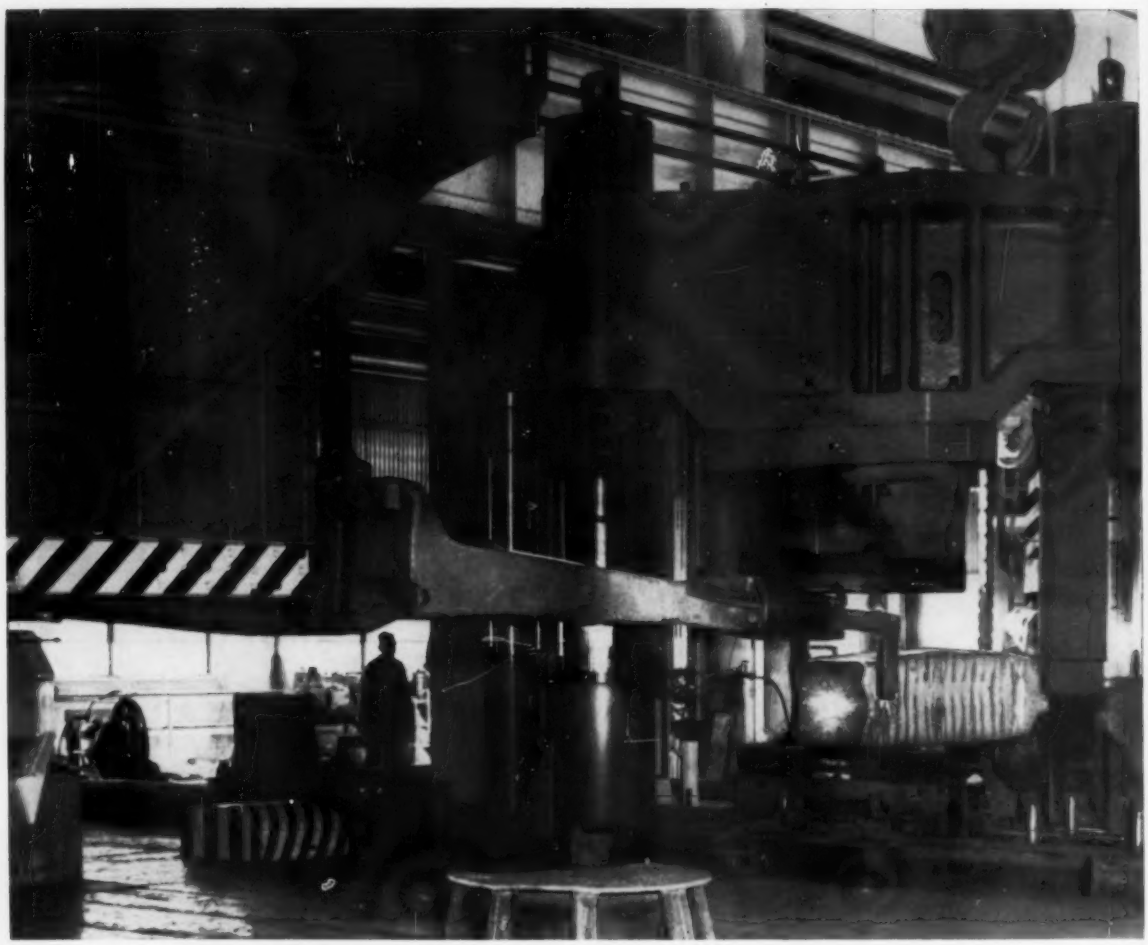
By J. H. JACKSON
*and H. B. GOODWIN**

As one of the mainstays of American production, the forging industry has progressed with the times since drop forging was introduced in 1846. Today, the industry is faced with new challenges from changing technological trends. What they are, and what they mean to forgers, is set forth in this article. (F22)

How will the advent of the space age affect the forging industry? What must the industry do to be technically prepared for the future? Clues to the answers can be found in technological trends strongly evident today.

Before noting some of these trends, however, a word on the present status of the industry is in order. To begin with, the basic drop forging tool, the steam drop hammer, has been in existence for over 100 years. The forging press has also been used for many years. During this long period, continuous improvement has been made in these conventional processes. Furthermore, many new processes have been developed, espe-

*Mr. Jackson is manager and Mr. Goodwin is consultant, metallurgy department, Battelle Memorial Institute, Columbus, Ohio. This article is the first of a series of three articles which are an expansion of a talk presented by Mr. Jackson at the 23rd Annual Meeting of the Drop Forging Association in June 1958. The second and third parts, which will discuss new forging methods and allied techniques, will appear in the next two issues.

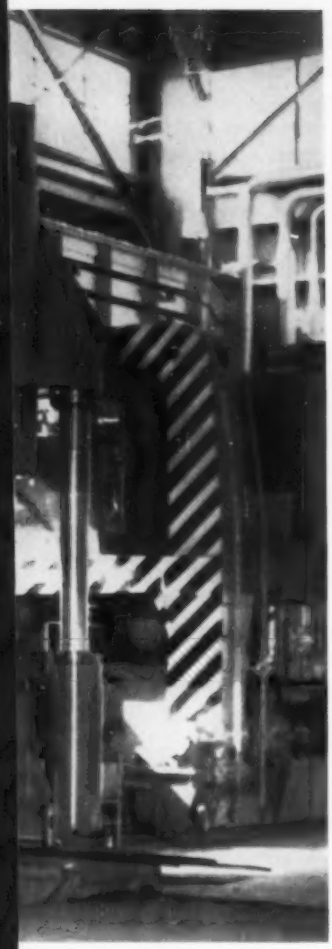


cially in recent years. Some of these will be reviewed in the next two articles in this series.

In the ten years through 1957, the dollar volume of forgings shipped increased more rapidly than the dollar volume of industry as a whole. (This period is taken to exclude the 1958 recession which makes more recent statistics difficult to evaluate.) Yet there is no room for complacency. During the last three years of this period (1955-57 inclusive), total *tonnage* of drop forgings shipped showed a continuing downward trend. Steel forging production as a whole was about the same in 1957 as it had been in 1954. The increasing dollar volume was due to a trend toward forging higher cost materials and more intricate shapes. It is true that automobile and farm machinery production declined after 1955 and that there was some military cutback in this period. Though financially sound, the forging industry cannot be content with a static tonnage in an otherwise rapidly expanding economy.

Growth of Research

What are some of the technological trends which the forging industry will have to consider in laying its plans for the future? Perhaps the most important technical trend of all is the tremendous growth of research and development in the last few years. As recently as 1929, the total U.S. expenditure for research, including military, agricultural, industrial, and medical research, was only $160 million. This was 0.15% of the gross national product for that year. By 1940, this had increased to $345 million, and by 1956 it had skyrocketed to $5 billion and amounted to 1.25% of gross national product. Thus, the ratio of research to gross national product was more than eight times as great in 1956 as in 1929. Re-



Drop Forge in Action

search is growing at the rate of 10 to 12% every year compared with an annual growth of 3% for gross national product.

Even if a company does not do a penny's worth of research, it will be profoundly affected by what its competitors do and by what its suppliers and customers do.

The Fundamental Approach

Metalworking is one of many technical fields in which future progress will probably have to be based on increased fundamental knowledge. It seems unlikely that the trial and error methods of the past can further improve hammers and presses to any radical degree. Real breakthroughs are more likely to come from more basic knowledge of the way plastic metal flows. We must learn more about the factors which influence the ability of metal to flow in dies and perhaps develop a mathematical analysis of metal flow.

Many instances from other areas of technology can be cited to illustrate a type of development that could hardly have been achieved through trial and error. Research on the atomic structure of materials has led to magnetic materials far superior to anything even dreamed of a few years ago, to semiconductors which make possible the transistor and have revolutionized the electronics industry, and to crystalline boron nitride (Borazon) unknown in nature and harder than the diamond. The likelihood that any of these could have been discovered by accident or by trial and error is exceedingly remote.

New Materials Pose New Problems

The general trend toward more power and speed in practically everything from lawn mowers to missiles has brought about a need for high-strength materials. These introduce new forging problems. The future tendency will be to use all materials more nearly to their maximum capabilities. Factors of safety will be less generous. For flight, obviously, light weight and small bulk are essential, but the trend will go far beyond flying vehicles. Considerations of economy, as well as increasing scarcity of many materials, will spur this trend.

To meet these conditions, steels of very high strength levels are coming into use. Within the past year or two, steels originally developed for making hot forging dies have been used successfully as aircraft structural materials. Right now, steels at an ultimate tensile strength of 300,000 psi. are being tried, and the development of steels of 400,000 psi. strength would not be surprising. The wide use of these steels will bring some problems. High strengths intensify certain hazards that are dormant or easily coped with at lower strength levels. These hazards include sensitivity to hydrogen embrittlement, to small surface defects including tool marks and scratches and to surface decarburization. These steels are also more difficult to weld, machine and form.

Most important to the forging industry is the fact that there is apt to be considerable difference between the longitudinal and the transverse properties of forgings made from these steels. In Table I, some properties of one of the ultra high-strength steels are shown. The much poorer ductility in the transverse direction is very evident, especially in samples cut from the

forging across the flash line. Also, more and more fabricators are specifying maximum transition temperature (as determined by impact tests) for forgings. Many of these high-strength steels do not have as much hot ductility as the materials used in the past.

Environments Are More Severe

Coupled with the trend toward higher stresses is a trend toward more severe environmental conditions. These include extremely high and extremely low temperatures, very rapid temperature changes, vibration, high intensity of radiation, action of corrosive liquids and gases sometimes moving at cavitating speeds, and many others. To cite a few examples, steam boiler temperatures have increased an average of 12° F. per year for 50 years, while inlet temperatures of jet engines are increasing about 15° F. per year. Many forged parts must operate in or near the hottest regions of these devices.

Unfortunately, the materials that are stronger at high temperatures are harder to hot forge and a lot more force is likely to be required. The industry has taken some steps to handle stronger alloys by increasing the size and power of drop hammers, but this procedure will soon reach a point of diminishing returns. Anvils and foundations eventually get so large and heavy that transportation and installation become extremely difficult. Devices like the counterblow hammer (to be discussed in Part II of this article next month) eliminate some problems, but need more development.

We are going to be forging titanium, the nickel and cobalt-base "superalloys", molybdenum-base alloys, and highly alloyed steels which will all pose special forging problems. Some of these materials also are so hard to machine that it is highly desirable to forge them to close tolerances. Little machining is then required. More and more materials will be "tailor made" for a particular use. Many applications will be so exacting that the requirements cannot be filled by alloys taken off the shelf. The forging industry will see a wide variety of materials developed for a particular use; for these, new processing cycles must be worked out.

New Materials Cost More

Not only are heat resistant alloys hard to forge; most are also quite expensive. Generally containing much nickel or cobalt, some cost several dollars a pound. Other metals even more expensive (molybdenum at about $10 to 20 a pound is a notable example) are beginning to interest missile engineers. Naturally, waste (in flash or trim, for example) is frowned upon in forging such materials. Many traditional practices based on cheap materials and expensive labor will have to be re-examined.

A trend that will make the forge shop's job difficult is the ever-increasing emphasis on precision. There seems to be little doubt that forgings will be made to ever closer tolerances in the years to come. There will be increasing pressure to achieve these tolerances without resorting to subsequent machining.

Many heat resistant alloys are now vacuum melted or degassed, and this helps the forge shop to some degree. Such materials are cleaner, more uniform, and of higher quality. On the other hand, contamination of these pure materials cannot be permitted. If some form of inert atmosphere is needed to protect the workpiece during forging, forgers will be faced with real problems. Few if any forging methods now in use can be adapted to atmospheric protection with ease.

Higher Costs Everywhere

While engineers dream up new hard-to-forge alloys and customers insist on their being forged without waste, labor and material costs continue to rise. Some steps can help, but they are not easy to apply.

Table I – Some Properties of a Forged Landing Gear Part Made of Tricent*

Property	Longitudinal	Transverse	Transverse Flash Line
Tensile strength	296,600 psi.	295,600	271,000
Yield strength (0.2% offset)	241,700 psi.	238,500	236,700
Elongation	8%	4	1
Reduction in area	23.0%	9.4	4.8
Charpy V-notch			
Room temperature	18 ft-lb.	9	7
32° F.	15	10	8
0° F.	16	7	9
−65° F.	15	7	7
−100° F.	10	6	7

*Source: International Nickel Co.

Electronic controls, so useful to other industries, are hard to adapt to most forging methods. However, they are coming. For instance, punch card programming of some operations is now being considered. There is little doubt that every industry will be using computers, control systems, data analysis, and other electronic techniques. Electronic controls are faster, more accurate, and more reliable than even the most skilled workman.

Some tentative moves are being made toward mechanization. A good example is the feeding mechanism for forging track links devised by Erie Foundry Co. (*Metal Progress*, November 1958, p. 116). Suitable for small parts, it feeds heated bars through a three-stage press. Only one operator is needed for monitoring. This is only a start in automatic operation; much more can and will be done as time goes on.

Some aid will come from rapid heating techniques now being improved upon and applied more widely. For instance, induction heating and radiant heating (often with protective atmospheres) are likely to become more common. Such methods will be valuable in automatic forging lines.

One factor opposing cost reduction efforts is the trend toward short runs. In the missile and aircraft field, for example, relatively small numbers of any one model will be built. Obviously, small numbers of individual parts will be needed for these models and this, to the forging industry, means short runs. In these fields, mass production of parts typical of the automotive field will not be seen. As a sidelight, this may result in forgers taking another look at die-making techniques.

Needed Research

What research should the forging industry do to be technically prepared for the space age? Basic to any research effort must be an improved understanding of the flow of plastic metal in dies. After all, that *is* the forging process. There have been investigations along these lines but the surface has scarcely been scratched.

For many years now Battelle Memorial Institute has been carrying out studies for the casting industry. These studies have helped produce sound castings with a minimum of wasted metal in sprues, gates, and risers. The same sort of work could be done for metal in the plastic state, the state it is in during forging. Phases of this research could include: study of the distribution of stresses in metal under impact and under pressure as a function of deformation speed; study of pressure distribution on forging dies; study of distribution of temperature and change of temperature with time (that is, of heat losses); development of mathematical treatment for predicting metal flow; and further study of the relation between properties, pressure during forging, and metal flow. Possibilities for improvement will appear automatically as more is learned about the process. Metal flow and die wear can be studied by radioactive tracer techniques. One could even determine variables which affect the practical limits of reduction.

As part of the fundamental study of the forging process, forgeability tests might well receive more attention. Numerous tests have been proposed but certainly none is universally satisfactory*. Another phase of fundamental research on forging might be a statistical study of dimensional variations in forging. If two forgings are produced consecutively in the same dies (so that die wear is negligible between the two), why are they not exactly alike? Where do dimensional variations come from? What are the causes of deviation from tolerances? Through statistical analysis, it should be possible to show the relative effect of such variables as size, shape, weight, density, and surface finish of the forging billet, temperature of dies, finish forging temperature, scale loss, energy of blows struck—especially the last—amount of flash, die wear, resilience of the foundation cushion material, and many others. Such a study could establish which factors are important and which are not.

Forging Studies for the Air Force

In short, the forging process should be studied intensively and systematically. A typical example will show what can be done. About four years ago, we began to study certain press forging and extrusion fundamentals for the Air Force.

Although the work was divided into five phases, only two of them will be discussed here. These were studies of the effect of variations in hot working reduction on the mechanical properties of certain steels and the effect of die and stock temperature on flow of metal during forging. (The other phases were concerned with the effects on required forging pressure of deformation rates, die roughness and lubricants.)

*See "Evaluation of Tests for Forging", by Alan B. Draper, *Metal Treatment and Drop Forging* (British), December 1957.

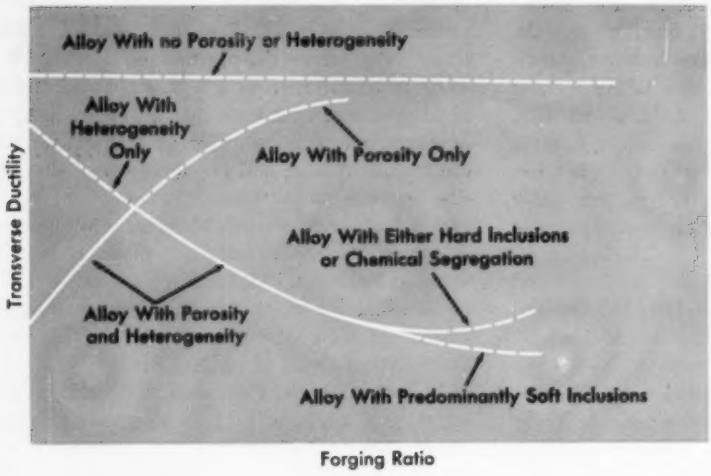
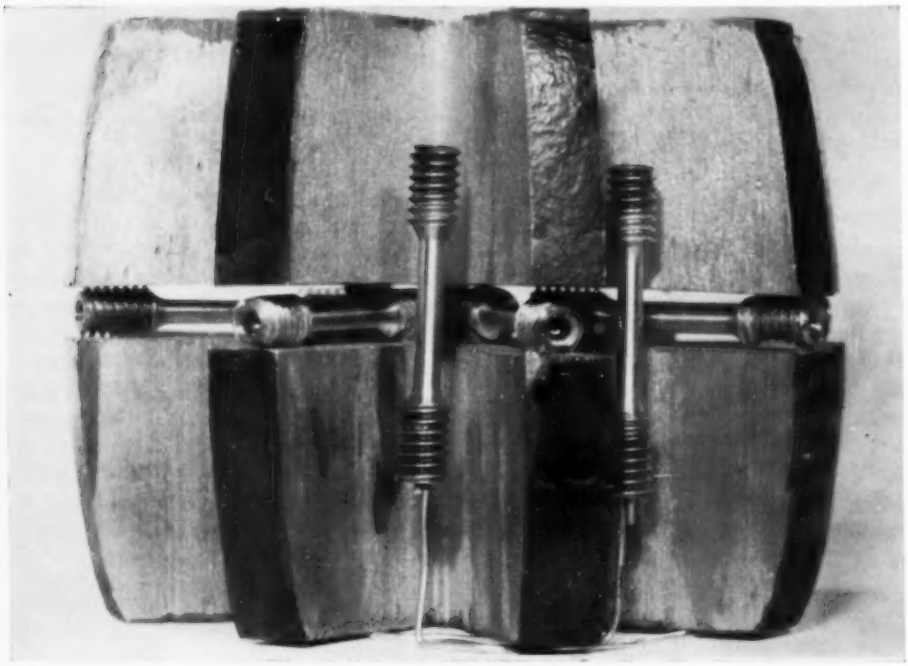

Alloy With no Porosity or Heterogeneity
Alloy With Heterogeneity Only
Alloy With Porosity Only
Alloy With Either Hard Inclusions or Chemical Segregation
Alloy With Porosity and Heterogeneity
Alloy With Predominantly Soft Inclusions
Transverse Ductility
Forging Ratio

Fig. 1 — Variation of Transverse Ductility With Forging Ratio

Before this work was started, it was well known that the effect of forging on ductility varies from steel to steel. Sometimes transverse ductility drops while longitudinal ductility increases with increasing amounts of forging. At other times forging improves ductility in both directions. In still other instances, ductility improves in both directions with a little forging, but on further forging transverse ductility again drops. The research was aimed at explaining the different behavior of the various steels.

It was speculated that varying degrees of porosity and heterogeneity might account for these differences. One would expect that in forging a material which was porous but otherwise homogeneous the closing of voids to form sound metal would increase both longitudinal and transverse ductility. Hence an alloy with

Fig. 2 — Cutaway of Forging Showing Tensile Test Locations



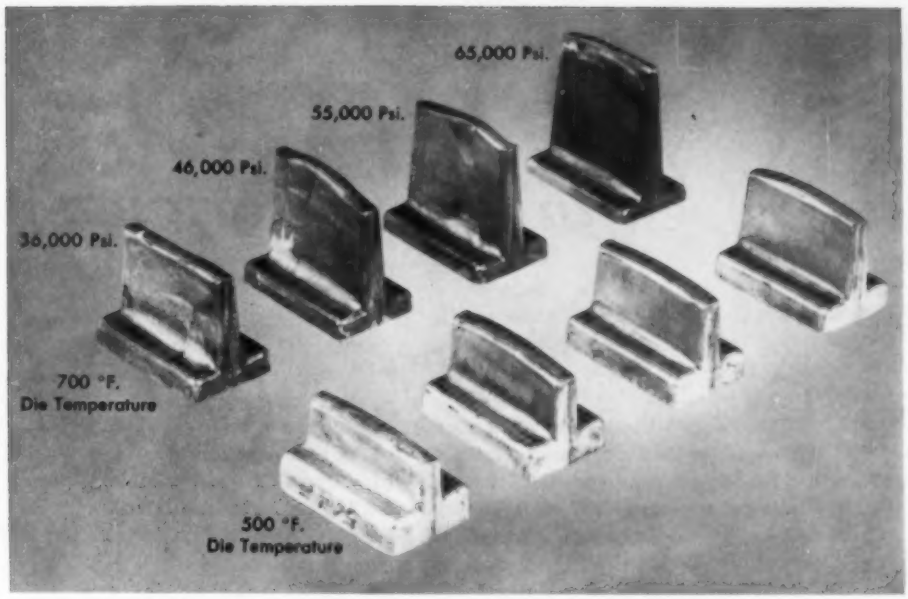


Fig. 3 — Effect of Forging Pressure and Die Temperature on Penetration. Metal flow improves with higher temperatures and pressures

porosity but with no heterogeneity would show improvement in transverse ductility with forging until all voids had been closed; after this, there would be little change. On the other hand, forging will change the shape of inclusions and segregates from spheres to stringers or disks (depending on the forging process). They will then have a much greater area in the transverse direction, and also form sharp "notches" within the material. Thus forging would be expected to have a detrimental effect on the transverse ductility of a steel with heterogeneity but no porosity to start with.

If a forging billet has both porosity and heterogeneity, some combination of the two effects can be expected. At first, transverse ductility will increase because voids are welded closed. With additional forging it will decrease again due to the stringing out or flattening of inclusions, segregates, or regions of chemical inhomogeneity. These effects are shown graphically in Fig. 1.

To check this hypothesis, experimental steels were prepared with controlled amounts of porosity and manganese sulphide inclusions and with varying degrees of chemical segregation. After forging to various ratios, tensile specimens, cut as shown in Fig. 2, were tested to determine transverse and longitudinal ductility.

Since the purpose of describing this research is to illustrate an *approach* which might be fruitful in future forging research, the detailed results, which are to be published elsewhere, will be omitted in this article. The hypothesis outlined was verified in a qualitative way but the story was found to be more complex than originally believed.

The effect of temperature on die flow also received attention. In one of these experiments, blanks were forced at varying pressures into dies at different temperatures. Figure 3 shows that higher die temperatures aided metal flow.

Challenge of the Future

In considering suggestions for future work, one must remember the two main essentials of forging. One is to get the part into the proper shape through plastic flow; the other, to improve mechanical properties. In planning research, the present state of the art and the status of competitive processes should also be considered.

While the forging industry need not be ashamed of its present standing, there is much to do in the future. To keep up with technology, forgers must be alert to all trends and even anticipate them before they appear. Only in this way can the forging industry progress in the future as it has in the past.

Progress in Forging

Hydrogen in Heavy Forgings

By J. E. STEINER*

Hydrogen causes flakes in heavy forgings and adversely affects ductility; consequently, much effort has gone toward hydrogen reduction. Investigation proved that lengthy heat treatments are not reliable, but that some hydrogen reduction is possible through careful melting. Finally, vacuum casting techniques solved the problem. (Q23p; ST, *H*, 9-70)

FOR MANY YEARS the standard 356 aluminigen plays an important role in thermal flaking. However, most of the early investigators conceded that a small residual hydrogen content was inevitable, and depended on heat treatments to prevent flaking. Though time-consuming, heat treatment controlled flaking quite well; flakes occasionally appeared, but forgers were generally able to produce sound forgings. They concluded that hydrogen, although troublesome, could be tolerated if proper heat treatments were employed.

In the early 1940's, many investigators realized that high hydrogen content had an adverse effect upon tensile ductility. This renewed interest in the hydrogen problem. Concern gradually increased as the size and alloy content of heavy forgings increased. In the early 1950's, catastrophic failures of several forged shafts in steam turbine generator units intensified efforts of both producers and consumers to improve the quality of heavy forgings. High on the list of their objectives has been the elimination of deficiencies of the forgings caused by hydrogen.

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Early Quantitative Appraisals

Fortunately, much earlier work sponsored by U. S. Steel and others had been done, and good hydrogen sampling and analytical techniques were available. In the early 1950's, we at U. S. Steel Corp. conducted several programs to measure the distribution of hydrogen across the

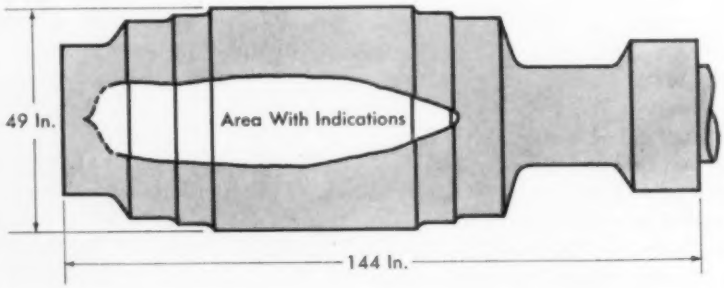


Fig. 1 – Distribution of Ultrasonic Indications in a Heavily Flaked Forging. Flakes occasionally occur, even though forgings of this size are given extensive flake prevention heat treatments. Residual hydrogen is responsible

Fig. 2—Flakes in Macro-Etched Transverse Section From Center of Large Forging. Such defects result in outright rejection

diameter of heavy forgings, and determine quantitatively the effect of hydrogen on the tensile ductility of forging steels. We also tried to develop better ways to control flaking. This work gave valuable insight into the nature and magnitude of the hydrogen problem in heavy forgings.

Flaking Causes Rejection

Probably the most widely known defect associated with high hydrogen in heavy forgings is thermal flaking. Flakes cause much concern, because their presence in a large forging means outright rejection. In addition, the industry bears the cost of lengthy heat treatments that are designed to prevent flaking. Heat treatment usually consists of an annealing, normalizing and tempering, or a double normalizing and tempering cycle. Because of the large masses involved, the time required for a simple normalizing and tempering treatment for the development of mechanical properties generally runs from five to ten days. To prevent flaking, however, additional slow cooling, isothermal holding, and normalizing and tempering cycles are often employed (in various degrees and combinations); these extra treatments can extend the total heat treating time to as long as 40 days.

In terms of what we know, a thermal flake is a tight crack formed by the combined action of hydrogen and stress. Always fully contained within a steel section, it generally appears as a disk unless directional stresses or localized weaknesses change the shape. Flakes may occur in most alloy and carbon steels of various conditions of cleanliness, homogeneity, and microstructure. The hydrogen content necessary for flaking probably varies widely with the composition, size, and degree of heterogeneity of the steel, and can be as low as 3 ppm. it is thought. As to hydrogen distribution, in a typical large forging with relatively high initial hydrogen content, it ranges from 1 ppm. near the surface to 5 or 6 ppm. at the center. The hydrogen content at the center of the larger forgings is reasonably representative of that of the liquid steel from which the forgings were made.

Ultrasonic Testing Is Helpful

Flaking in a heavy forging as revealed by ultrasonic inspection is shown in Fig. 1. A macro-etch test, representing a 16 × 16-in. transverse section from the center of this forging, is shown in Fig. 2. Each of the fine hairline cracks represents either a chord or a diameter of a flake which is roughly circular. Although these flakes are large, in comparison with those found in lighter steel sections, some are even bigger.

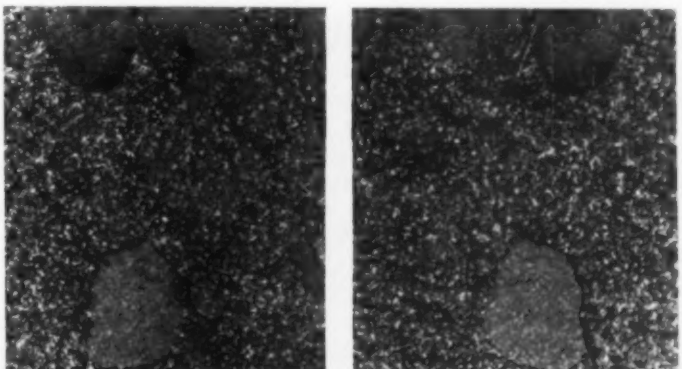


Fig. 3—Fracture Surface of Flakes. Normally they are roughly circular, but directional stresses and local weaknesses can change the shapes

Flakes as large as 3 in. in diameter have been observed in some heavy forgings. The shape and "brightness" of flakes are readily visible in fractured sections, as Fig. 3 shows.

In addition to sectioning and examining rejected forgings, we made systematic attempts to evaluate and control flaking. As expected, these studies showed that flake sensitivity increased with hydrogen content. Though no new means for flake control appeared, the work confirmed the accepted rule that either a very low hydrogen content or special safety treatments are needed if flaking is to be avoided.

Flakes are generally oriented within (or parallel to) the forging grain pattern or segregation pattern. Further, small highly alloyed zones resulting from localized segregation are found within the segregation pattern of many alloy steel forgings and are extremely sluggish in transforming. On occasion, a flake-prevention treatment that transforms the base steel and most of the segregates is not adequate to transform these small zones. These zones may then transform at room temperature after heat treatment, and this transformation may add enough stress to achieve the critical stress for flaking. The foregoing is only one explanation for flaking; in other hypotheses, nonmetallic inclusions, microporosity, and lattice discontinuities have also been proposed as potential nucleating sites.

"Fisheyes"

"Fisheyes" is the term used to describe small shiny spots occasionally observed on the fracture surfaces of tension-test bars from "high-hydrogen" alloy steel forgings or alloy steel heavy plates (Fig. 4). Despite the fact that they occur infrequently, they are noteworthy because of their dependence on hydrogen. Usually, a high hydrogen content in a test bar will merely lower ductility; thus hydrogen alone is not sufficient to cause fisheyes. A nucleating site (usually a nonmetallic inclusion or pore) is also necessary. Upon close examination of fisheyes, these sites, the "pupils", can usually be observed at the center.

Aging can remove hydrogen, at least in test bars made from forgings containing hydrogen. For example, when another bar (from the same location as the one illustrated by Fig. 4) was aged at 500° F. for 1 hr. and then pulled, the resulting fracture did not show fisheyes. The experiment was repeated on tests taken in the transverse direction with similar results. In the June 1946 issue of *Metal Progress*, Gross, Angell and Marshall reported fisheyes in test bar fractures of manganese-vanadium, manganese-titanium, and manganese-vanadium-titanium plate steels. They also mentioned that the tendency for fisheyes to form decreases with time as hydrogen diffuses out of the steel.

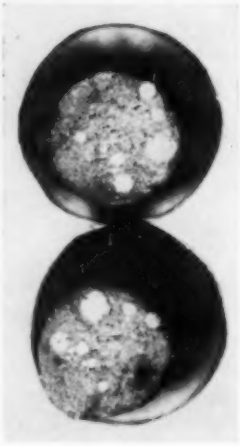


Fig. 4 — "Fisheyes" in the Fracture Surfaces of a Test Bar. Partly caused by hydrogen, these generally nucleate at a nonmetallic inclusion or a pore. They will not appear if bars are aged at 500° F. before testing; hydrogen diffuses out during this treatment

These observations have led the author to believe that fisheyes occur as follows. When sufficient hydrogen is present in a heavy section of a high-strength alloy steel containing nucleating sites, such as those described above, hydrogen diffuses to these sites either before or during tensile testing of bars from these sections. The accumulated hydrogen at these sites builds up pressure that is insufficient in itself to cause even microcracking of the metal. However, as external stress is applied during tensile testing, the applied stress combined with the stress exerted by the accumulated hydrogen causes microcracks to form at these sites prior to the actual fracturing of the tensile specimens. Hence, the shiny spots observed on the fracture surfaces are the surfaces of the small cracks that formed internally during tensile testing.

Although fisheyes are observed only in the fracture surfaces of tests (and consequently cannot to be classed as defects in steel products), they are of particular interest because the formation mechanism can be compared with that for flakes. Each depends upon the presence of hydrogen and stress. Since fisheyes require nucleating sites, it also seems logical that similar sites would be needed to initiate flakes.

Hydrogen Lowers Ductility

Potentially, the most serious hydrogen problem is its effect on tensile ductility. This is illustrated by Fig. 5. Prior to this discovery, the

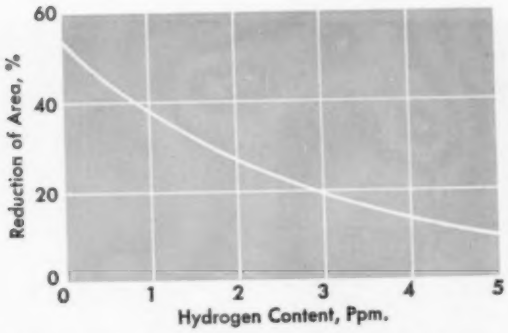


Fig. 5 – Effect of Hydrogen on Transverse Reduction of Area. In modern practice, hydrogen is regularly lowered below 2 ppm. by vacuum casting

transverse tensile ductility of many large forgings was inexplicably erratic. "Resting" the test bars for a few weeks at room temperature before they were pulled generally restored the ductility. Further, aging for 1 hr. at 500° F. accelerated the effect. We now know that both "resting" and aging allow hydrogen to diffuse out of the test bars.

Unfortunately, this effect quickly reaches a point of diminishing returns as the thickness of the steel is increased. For example, we estimate that, at 1275° F., the time required to lower hydrogen from 5 to 1 ppm. at the center of a solid forging would be about three days for a piece 10 in. in diameter. This rapidly increases to 12 days for a 20-in. forging and 75 days for a 50-in. diameter.

Because many of our forgings are more than 45 in. in diameter, the removal of hydrogen by diffusion methods was not practical.

Experiments in Hydrogen Reduction

The next step was to find out whether hydrogen could be removed during melting or casting. Although we wanted to eliminate hydrogen completely, our initial goal was 1.5 ppm. max. for a typical rotor steel.

After much preliminary work, the program expanded to include sampling throughout the melting of electric furnace and openhearth rotor heats. Since results indicated that the moisture content of the furnace atmosphere might play a significant part in hydrogen pickup, we began to sample openhearth heats melted under both "wet" and "dry" atmospheres.

Following this, we evaluated the effect of both steam and air atomization of fuel on the hydrogen content. Slag samples were also analyzed to examine the influence of oxygen availability and slag basicity. From this work, we concluded that a relatively low hydrogen content in a melt could be attained by maintaining a low water content in the furnace atmosphere and a slag of low basicity and high FeO content.

In the December 1957 issue of *Journal of Metals*, Kerlie and Richards summarized these experiments by the following empirical equation:

$$\underline{H}^2 = \frac{10\,B\,(H_2O)}{FeO}$$

where H = hydrogen dissolved in steel in ppm.,

B = slag basicity $\dfrac{CaO\ (\%) + 0.39\ MnO\ (\%)}{0.93\,SiO_2\,(\%) + 1.18\,P_2O_5\,(\%)}$

H_2O = water in furnace atmosphere (% by volume), FeO = total iron oxides in the slag (calculated to FeO in %).

With this equation, hydrogen content of liquid metal during the finishing period of an openhearth heat can be predicted with about the same certainty that it can be measured.

Vacuum Casting Solves the Problem

As these concepts were being formulated, and lower hydrogen contents appeared to be within reach, the vacuum casting process came under consideration. Calculations indicated that this method could lower hydrogen significantly below the minimum of 2.0 ± 0.8 ppm. which was estimated as the potential limit that could be achieved by the closest control of conventional melting.

Accordingly, we decided to try full scale vacuum casting. A unit which could vacuum cast ingots up to 110 in. in diameter was installed at U.S. Steel's Duquesne Works, and operated successfully. Rotor forgings from the vacuum cast ingots have a hydrogen content throughout their cross sections of about 1 ppm. with no indication of hydrogen segregation.

Experiments showed that rotor steel from vacuum cast heats could not be flaked by the most severe tests. More important, all forgings produced to date have exhibited no significant differences in ductility between aged and unaged tension tests. There was also complete freedom from flaking.

In summary, experience and research indicated that the major problems of flaking and lowered tensile ductility in heavy forgings can best be solved by lowered hydrogen content. Vacuum casting has so far proved to be the most effective way to lower hydrogen content and eliminate the major hydrogen problems.

Heavy Precision Forgings Are Formed on Alcoa's 50,000-Ton Press. These two forgings, made of 2014 aluminum, are depicted in Fig. 2 and 3; the one being weighed replaced the other which was an earlier design

Progress in Forging

Forging With King-Size Presses

*By A. E. FAVRE**

Alcoa's large forging presses, which include a 35,000 and a 50,000-ton model, are used to make precision forgings for aircraft and missiles. Though first cost is higher, savings in machining more than compensate for this. (F22, W22p; Al)

THE ADVENT of heavy forging presses has revolutionized light metal forging in this country. However, advances have not come easily. Every step has been accompanied by high development costs, failures, and loss of time. Vision and extreme effort were required from both the engineers in the airframe industry and the operators of Air Force heavy press equipment. Through their cooperation, full use of this heavy production equipment was achieved.

Some of the Problems

Forgings made on large hammers were generally designed with 7° draft angles, heavy webs, large fillets and corner radii; these forgings often have to be completely machined on all surfaces. The action of a hammer itself usually limits the precision to which a large forging can be produced. For example, the severity of the impact blow makes it difficult to use heating equipment to maintain high constant die temperatures. (This would keep the metal in thin areas in a plastic state.) Also mechanical ejectors, needed to knock out a part that has low or zero draft angle, are difficult to maintain in dies.

The slow constant squeeze of a hydraulic press overcomes these difficulties, and enables forgings to be produced with closer design tolerances and less draft. Another advantage of the hydraulic press is that it does not dissipate its energy at the end of the stroke. Instead, it can maintain full load and dwell for a given period of time under full pressure. This helps the soft metal to fill the die cavity. Dies on a hydraulic press also last much longer than they do on a hammer.

The heavy forging presses operated by Alcoa for the Air Force include an 8000-ton, a 15,000-ton, a 35,000-ton and a 50,000-ton hydraulic press. In addition, a 1500-ton hydraulic press and a 25,000-lb. steam hammer are located at the Alcoa plant at Vernon, Calif. In operating this mammoth equipment, we have had two primary

*Assistant to Plant Manager, Cleveland Forge Shop, Aluminum Co. of America, Cleveland.

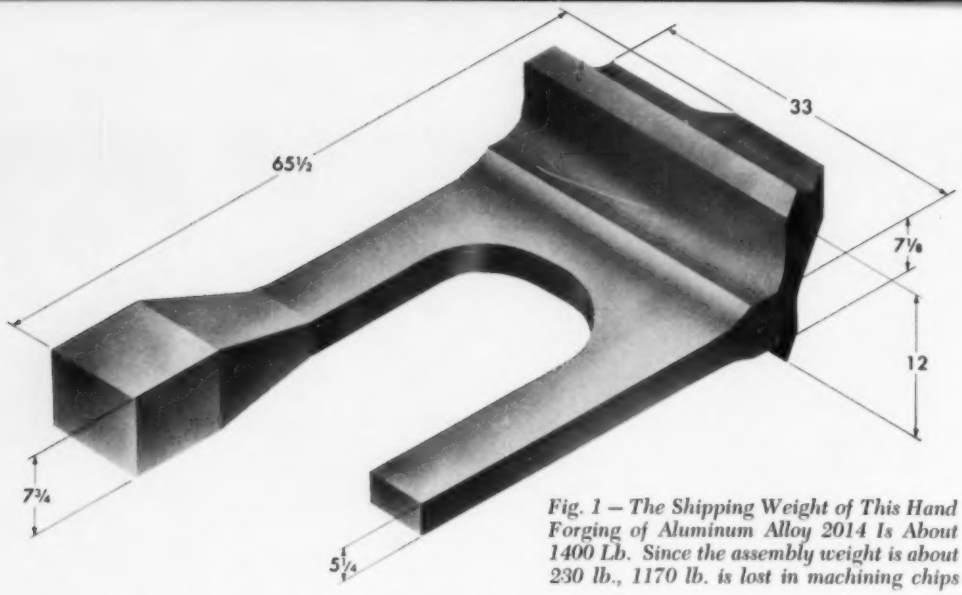


Fig. 1 – The Shipping Weight of This Hand Forging of Aluminum Alloy 2014 Is About 1400 Lb. Since the assembly weight is about 230 lb., 1170 lb. is lost in machining chips

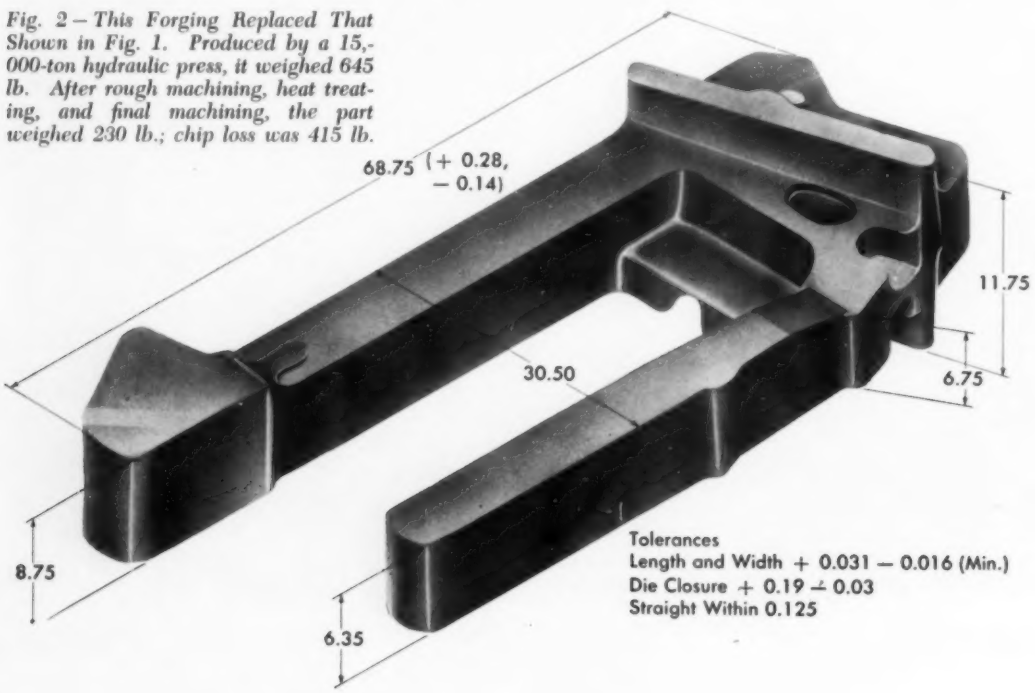
goals in mind – goals our customers have set for us. We wanted first to produce forgings of a size far beyond the capabilities of large hammers, and, second, to produce these forgings with as little machining allowance as possible.

These goals were needed to meet the demands of aircraft powered by turbojet engines. To take advantage of the greater power of these engines, and to obtain top efficiency in such aircraft, maximum weight reduction was necessary. To do this properly, built-up structures had to be eliminated. The large forgings that were required involved die blocks too large for hammers. (Many die blocks in use today weigh 10 to 20 tons, and some die blocks ordered by Alcoa weigh almost 50 tons.)

As forgings became larger and more complex, the length of time and cost of machining (along with the lack of proper machining equipment) presented a serious problem. Aircraft manufacturers and forging producers began research to find what could be done to improve forging design, obtain closer tolerances, reduce costs, and minimize the long lead time then needed to obtain the finished product.

Up to this stage, large forgings were produced on large steam hammers. Now, larger forgings were to be produced on these large hydraulic

Fig. 2 – This Forging Replaced That Shown in Fig. 1. Produced by a 15,000-ton hydraulic press, it weighed 645 lb. After rough machining, heat treating, and final machining, the part weighed 230 lb.; chip loss was 415 lb.



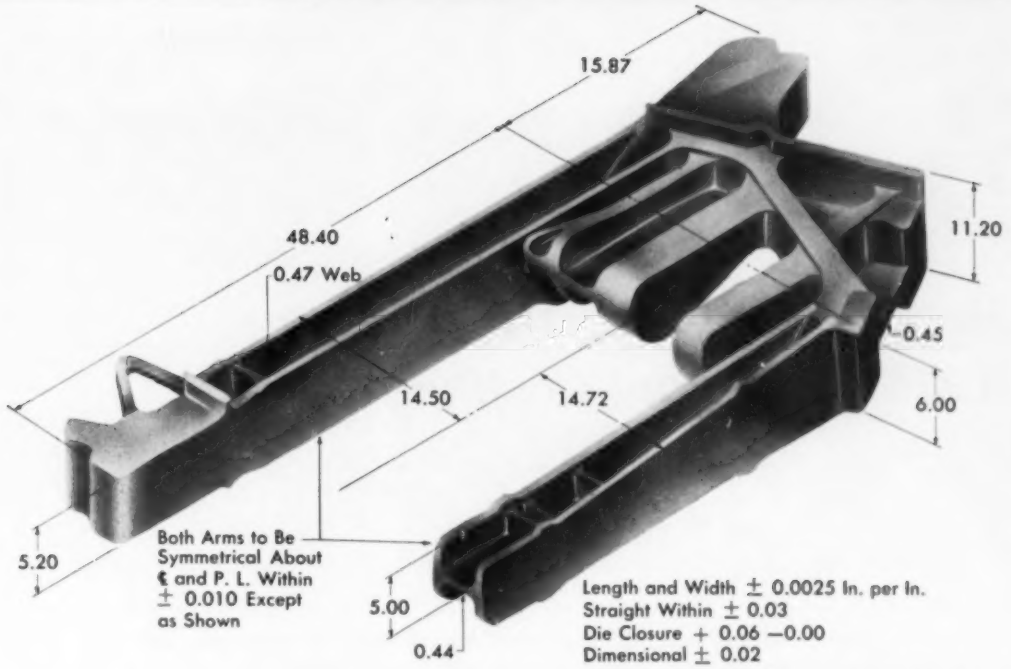


Fig. 3 — Made on a 35,000 or 50,000-Ton Forging Press, This Precision Forging Superseded Those Shown in Fig. 1 and 2. Since it weighs 290 lb., only 60 lb. is lost in machining

presses. But along with this, precision forgings were being considered by aircraft engineers. Their studies indicated that precision forgings saved time and money. The results were such that, even on conventional forgings where tooling was available and the quantity requirements were large enough, new tooling was ordered and constructed to obtain a precision forging. These changes not only applied to the large forgings, but also proved to be economical in making forgings on smaller presses.

Large Forgings at Present

Having traced the development of heavy press equipment, let us look at present capabilities. Design proportions and tolerances we are capable of today are listed below:

1. Forgings have been produced with webs as thin as 0.100 in. in boxed-in areas.

2. Fillet and corner radii have been reduced on an average to about half of those formerly produced.

3. Length and width tolerances can be cut down considerably since constant high die temperatures can be maintained. Tolerances on long dimensions have been reduced to as little as ± 0.001 in. per in., with 1/32 in. additional allowance on all die contacting surfaces. (This allowance is used primarily for die polishing and die cleanup between production runs.)

4. Die closure tolerances can be reduced in some instances to + 0.030 in.−0.010 in., depending on alloy, size and design of the part.

There are some problems. High-strength alloys such as 7075 and 7079 are more difficult to forge, for example, than 2014, 6151 and 6061, all of which are frequently used by the aircraft industry. These alloys require higher unit pressures to forge, thereby limiting the size of a forging which can be produced by any given piece of forging equipment. Also, design proportions, in general, must be more liberal.

To determine what can be achieved for an individual part, the early stages of design require consultation between engineers of the forging producer and engineers of the buyer. Each forging design is a study in itself. It is, therefore, difficult to set down design proportions and tolerances that would cover all types of forgings of a precision nature.

As an example of what has been done by this new equipment, examine Fig. 1, 2 and 3. They illustrate the same part forged three different ways. Machining loss was lowered from 1170 to 60 lb. through precision forging.

It should be pointed out that it takes a longer time to ready a precision forging for production. Likewise, the initial cost of tooling and the piece price for a precision forging can be two to five times that of a conventional forging. This depends, of course, upon the design and tolerance requirements of the part. However, an over-all saving on the net product can be realized by the lower assembly and machining costs.

Mechanical Properties of A356 Aluminum Casting Alloy

*By G. N. REINEMANN and L. E. MARSH**

Since tensile strength and elongation depend so much on freezing rate, the foundry engineer should be given a full stress analysis of a complex casting so he can properly place gates, risers and chills. (Q27a, E25; Al-b)

FOR MANY YEARS the standard 356 aluminum alloy (nominally 7% Si, 0.3% Mg) has been used for castings which require good ultimate and yield strengths in combination with substantially more ductility than could readily be achieved with other common aluminum foundry alloys.

High-purity alloy A 356, which has the same nominal composition but with impurities, particularly iron, controlled to lesser amounts, gives a very desirable combination of high strength and good ductility. It also has excellent foundry characteristics, so that the inherent properties can be realized in many more complex shapes.

In evaluating this alloy, we used the same basic procedures and test castings as in a similar investigation of C 355 alloy described in the August 1957 *Metal Progress* in an article entitled "Mechanical Properties of C 355 Aluminum Casting Alloy", written by T. H. Owen and L. E. Marsh. The test casting, as described fully in the article quoted, is a flat slab, 6 in. wide, 12 in. long, and ¾ in. thick, poured and fed from one end and chilled across the opposite end. From this, several standard 0.505 × 2-in. tensile test bars were cut and the effect of solidification rate could be evaluated, ranging from freezing requiring 40 sec. near the chill to 15 min. near the riser. The ¾-in. thickness is representative of the heavier aluminum castings used in high-stress applications. As in the former study, separately cast test bars were obtained from each heat.

The investigation was carried out in two parts. The first part evaluated the normal unmodified alloy and the effect of a rapid quench. The second part dealt mainly with the effects of sodium modification of the Al-Si eutectic on the mechanical properties.

Unmodified Alloy

The procedure for a typical heat for the first part of this study was as follows: 180 lb. of prime ingot was melted in a 400-lb. gas-fired tilting furnace, raised to 1400° F., skimmed and then fluxed with dry nitrogen for 40 min. The metal was again skimmed and three test slabs and one plate of separately cast bars were poured at 1310° F. Three slabs and three separately cast test bars from each of the four heats of prime ingot were solution treated at 1000° F. for 14 hr., quenched in boiling water and aged 5 hr. at

*Mr. Reinemann is a metallurgical engineer and Mr. Marsh is manager of casting development, Morris Bean & Co., Yellow Springs, Ohio.

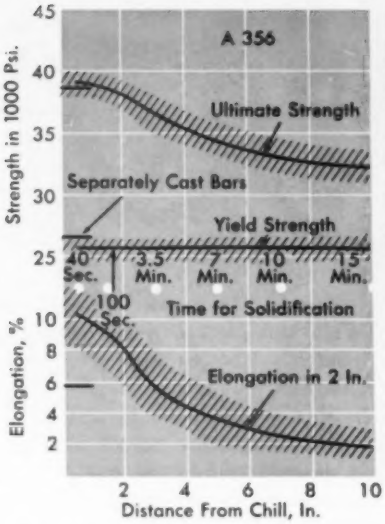


Fig. 1 – Mechanical Properties of A 356, Degassed With Nitrogen, Cast in ¾-In. Slabs, at 1310° F., Solution Treated at 1000° F. for 14 Hr., Quenched in Boiling Water, Aged 5 Hr. at 310° F. (T 6 Condition)

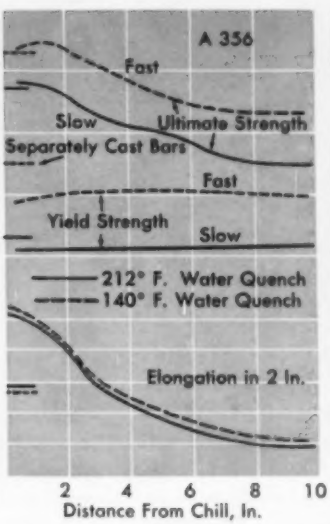


Fig. 2 – Effect on A 356 Castings of Faster Quench (140° Water) After Solution Treatment

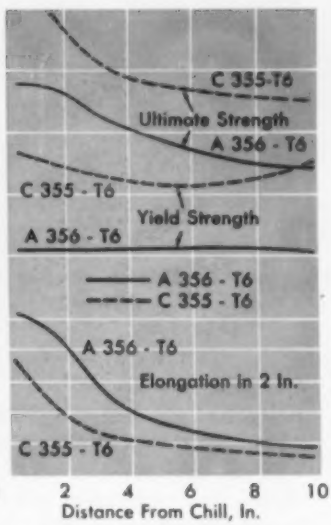


Fig. 3 – Comparison of Mechanical Properties of A 356 and C 355 Castings in the T 6 Condition

310° F. Three additional slabs cast from one of the heats were similarly heat treated except that they were quenched in 140° F. water. All test slabs were radiographed and were consistently excellent in appearance.

The average mechanical properties obtained from various locations in the slabs are shown in Fig. 1 and the average for separately cast bars is shown in short lines at the left. The shaded areas show the scatter of results as measured by the standard deviation. The standard deviation from the mean for elongation of A 356 is in the order of ±2%. (Compare this with ±0.5% for C 355 as noted on p. 81 of *Metal Progress*, August 1957.) This decrease in consistency is due primarily to two factors: first, a decrease in the total number of bars pulled in the present study of A 356, and second, its increased ductility (about doubled) resulting in greater "neck down" which seems to accentuate any minor imperfection at the point of fracture.

The effect of more rapid quenching (140° F. versus boiling water) is shown in Fig. 2. While there is very little increase in the elongation, the yield strength is increased from 26,000 to 30,000 psi., or 15%, and the ultimate strength is raised an average of 3500 psi., approximately 10%. By shortening the aging time, the elongation can be increased while maintaining approximately the same strength values obtained after a boiling water quench.

Rapid quenching would often be most unwise because it would introduce higher residual stresses into the part. Since this alloy possesses a fair amount of elongation, it is possible that the high residual stresses in a rapidly quenched casting would be relieved by service straining without premature failure. The ultimate load at failure might even be increased. However, depending on the direction and magnitude of the residual stresses, the load required to cause deformation would be changed, and if the elongation were inadequate to relieve the stresses, a premature failure might result. Residual stresses also affect casting stability and load-carrying ability under fatigue stresses. For these reasons, the actual application of the casting should be carefully considered before it is decided that the increased mechanical properties after a rapid quench will actually result in superior performance.

Figure 3 compares the properties of unmodified A 356 alloy in the T 6 condition with the corresponding high-purity C 355 alloy described in *Metal Progress* for August 1957. This comparison emphasizes not only the higher ductility of A 356 alloy but also its lower strength. Obviously, each alloy has its own advantages; the choice would depend upon the particular application. It is interesting to note that the elongation curves show very nearly identical properties

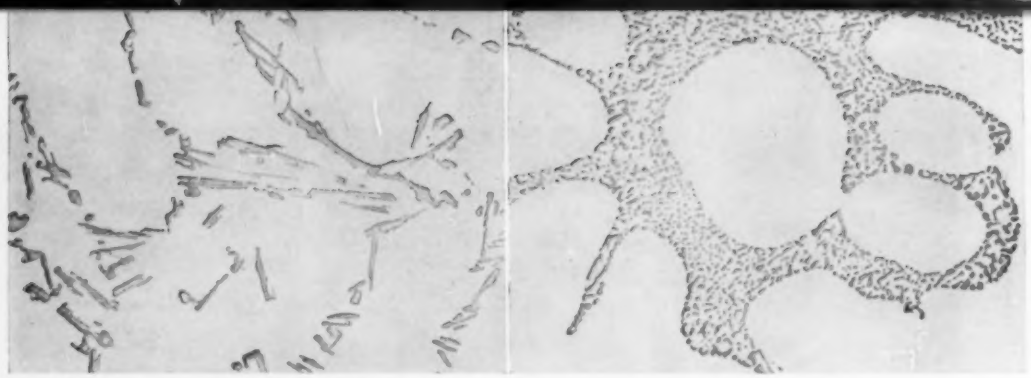


Fig. 4 – Microstructure of Al-Si Eutectic in A 356 Alloy, Unmodified (Left) and Modified With Sodium. 175 ×. Etched with 5% HF

8 to 10 in. from the chill – that is to say, near the riser – and the higher elongation of the A 356 alloy becomes apparent toward the chilled end. This indicates that the A 356 alloy must be well chilled and well fed in order to obtain the inherent advantages of high ductility. Its advantages in slow freezing heavy sections may be insignificant, particularly if the lower strength is a consideration.

Modified Alloy

The second part of this evaluation, dealing with the effect of modification on the mechanical properties, was run separately, mainly because of the problems encountered in obtaining gas-free metal after introducing the sodium. If conventional practices were used to add metallic sodium or sodium salts to a well-degassed heat of metal, the gas content increased to an unacceptable level. Such metal would not meet the high quality requirements of many applications.

A lengthy series of experimental heats was made before a proper method was developed. The procedures eventually adopted result in good modification of the aluminum-silicon eutectic with very little or no increase in the gas level of the metal. Disclosure of our methods will be reserved for the present, until patent protection can be secured. Microstructures of the alloy, as cast, in the unmodified condition and after modification with silicon, are shown in Fig. 4.

The foundry procedure for the second part of the investigation was altered so that unmodified and modified slabs could be cast from the same foundry melt. Only one heat of supplier's ingot was used (see Table I); 300 lb. was run down in the 400-lb. gas-fired furnace. The temperature was raised to 1400° F. and the metal was degassed with dry nitrogen for 50 min. The bath was skimmed and two test slabs and one plate of bars were poured. The remaining metal was then modified and three test slabs and one set of bars were poured. The castings were heat treated as in the first part of this study.

Evaluation of Gas Content – It is a well-accepted fact that the addition of sodium to aluminum-silicon alloys increases the gas content, but there is a considerable difference of opinion as to the amount and its effect on the radiographic quality of the casting. These differences of opinion probably result not only from the actual differences in the amount of gas added and the method of evaluating it, but from the nature of the castings being poured and the thermal conductivity and capacity of the mold.

Since the freezing time in the ¾-in. test slab casting, end to end, varies from less than 40 sec. to more than 15 min., radiographs of such a piece offer a reliable and sensitive method of determining gas in the heat. Such slabs also show why there can be considerable differences in the radiographic quality of castings poured from metal containing about equal amounts of gas.

Metal must be extremely well degassed and carefully handled if slabs ¾ in. thick which are completely free of gas porosity on a radiograph are to be obtained. As the gas content of the metal increases, the porosity shows up first in the slowest freezing section of the slab near the riser. Further increase in the gas content is indicated by an increase in the size of the gas porosity at the riser end and also an increase in the distance from the riser where the porosity

Table I – Alloy Composition of Ingots

	Si	Mg	Ti	Cu	Fe	Zn
Part I						
A Supplier's ingot (two heats)	7.03	0.35	0.09	0.01	0.12	0.00
B Supplier's ingot (two heats)	6.92	0.35	0.10	0.01	0.10	0.02
Part II						
Supplier's ingot (one heat)	6.89	0.34	0.12	0.06	0.11	0.01

Fig. 5 – (Left) Mechanical Properties of A 356 as in Fig. 1 and After Modification With Sodium (T 6 Condition)

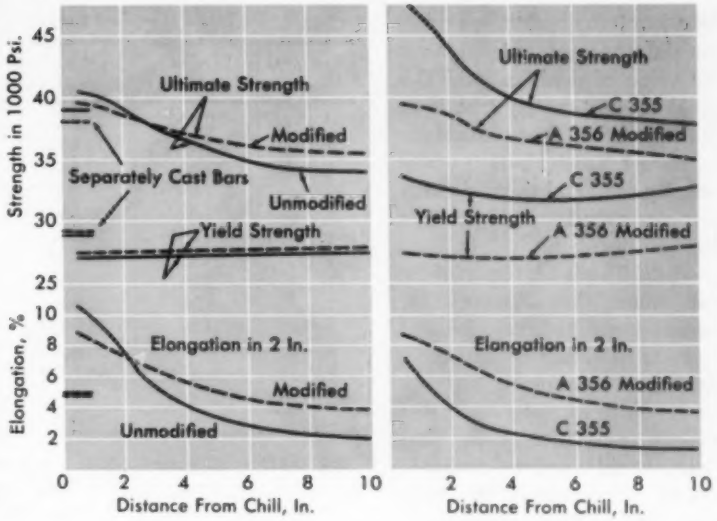


Fig. 6 – (Right) Comparison of A 356 (Sodium Modified) and C 355, Both in T 6 Condition. Solution heat treatment: 14 hr. at 1000° F. for A 356, 14 hr. at 980° F. for C 355

can be seen. With a relatively high gas content, the porosity will become very coarse at the riser and extend to within 1 or 2 in. of the chill. Thus, the radiographic quality of a casting depends both on the gas content and the freezing rate. Thin-walled or highly chilled sections can tolerate a relatively high gas content before there is any radiographic indication of porosity, vice versa for heavy or slow-freezing sections. Those castings which by nature of their design can tolerate a moderate amount of gas without porosity indications can usually be successfully produced even when conventional sodium modification procedures are followed. Many sodium-modified castings, however, because of heavier sections or other design features, cannot be produced with porosity-free radiographic quality unless special modification techniques are used.

The radiographic quality of the risered end of a ¾-in. slab may correspond to the "1.21 No. 1" rating given in the Navy Technical Inspection manual (NAVAEROO-15 PC-504) for round gas porosity. Castings with the same gas content as this slab will show no radiographic indication of gas porosity because of the more rapid freezing rate of the usual casting. The same metal will also give a radiographically sound specimen if frozen under reduced pressure.

With the conventional sodium modification procedures, we could not produce a ¾-in. slab with well-modified metal as good as the Navy 1.21 No. 1 rating, even though a slab poured from the metal just before modification was completely sound radiographically. Our special techniques produced slabs for the second part of this investigation equal to or better than the Navy 1.21 No. 1 rating at the risered end.

Physical Properties of Slabs – Figure 5 compares the results of our tests on unmodified and modified heats as made in the second part of the investigation. It will be noted that the values for yield strength given in Fig. 5 are all slightly higher than the average values plotted in Fig. 1, which resulted from an adjustment in the 0.2% offset value.

It is apparent that the main benefit of modification is to increase the elongation. The elongation and the ultimate strength curves cross at a point representing metal 2½ in. from the chilled end of the slab. These curves represent averages from four melts. Results from the individual slabs indicate that, while the tensile strength of the modified metal falls very close to the average values shown in Fig. 5, the unmodified metal shows considerable variation up to 4 in. from the chill. Some slabs of unmodified metal have elongation curves of the "S" form shown in Fig. 1 and 5; in the others the properties rise generally toward the chill. In all of them, however, the curves cross or meet in the region near the chill. (The values for yield strength are nearly constant throughout the slab for both modified and unmodified metal.)

This variation in elongation and ultimate values toward the chilled end of unmodified slabs has occurred more or less at random throughout the investigation. Curves plotted from individual slabs poured from identical metal and heat treated together show the same variation. No logical reasons for this can be advanced at this

time, but it may partially explain the difference of opinion as to the value of modification. This could be particularly true if an evaluation had been made on separately cast bars, whose freezing rates and thermal gradients correspond approximately to those in the slab 3 to 5 in. from the chill. This is the region of the slab where the difference between test results on modified and unmodified metals varies from a significant amount to little or none. Since freezing conditions present in separately cast bar molds could vary considerably due to differences in the mold properties and design, and since, in addition, there are evident variations in response to modification in that particular freezing range, a reliable conclusion would be difficult to reach.

It is evident, however, that sodium modification of the eutectic does provide consistently higher elongation properties in the slower freezing areas of the slab. Its benefits, if any, in highly chilled areas of A 356 castings are very doubtful.

Table II – Test Bars Cut From Support Arm

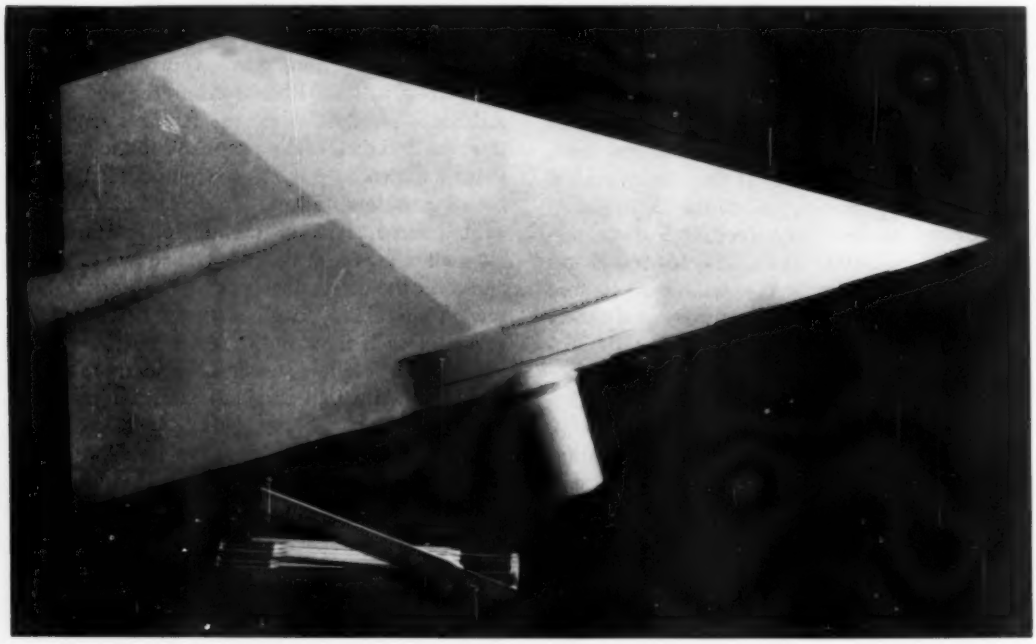
Bar and Size	Section Thickness	Ultimate Strength	Yield Strength	Elongation	Brinell Hardness
A *(a)*	2.62	31,000	—	3.0	70
B *(a)*	2.62	32,600	—	4.0	—
C *(a)*	2.69	37,600	—	11.0	70
D *(a)*	2.69	36,600	—	14.0	—
E *(a)*	3.0	30,600	—	3.0	80
F *(a)*	3.0	30,700	—	3.5	—
G *(b)*	0.38	35,200	—	10.0	70
H *(b)*	0.38	35,800	—	10.0	—
I *(b)*	0.38	37,600	—	13.5	70
J *(b)*	0.38	35,400	23,400	10.5	—
K *(c)*	0.5	39,800	24,400	11.0	77
L *(c)*	0.5	36,200	25,300	8.0	—
Separate cast	—	26,000	23,800	6.0	—

(a) 0.375 in. diameter, 1.5 in. gage length.
(b) 0.312 in. diameter, 1.5 in. gage length.
(c) 0.375 in. diameter, 2 in. gage length.

Figure 6 compares the A-356 alloy in the modified T 6 condition with C 355-T 6. The former possesses higher ductility throughout the entire range of freezing rates although, as before, the strengths are significantly lower. It should be noted that aging times for A 356 after solution treatment can be varied to give a wide combination of strength and ductility.

Production Castings – Figure 7 is a photo-

Fig. 7 – Fin Casting for a Missile Made in A 356



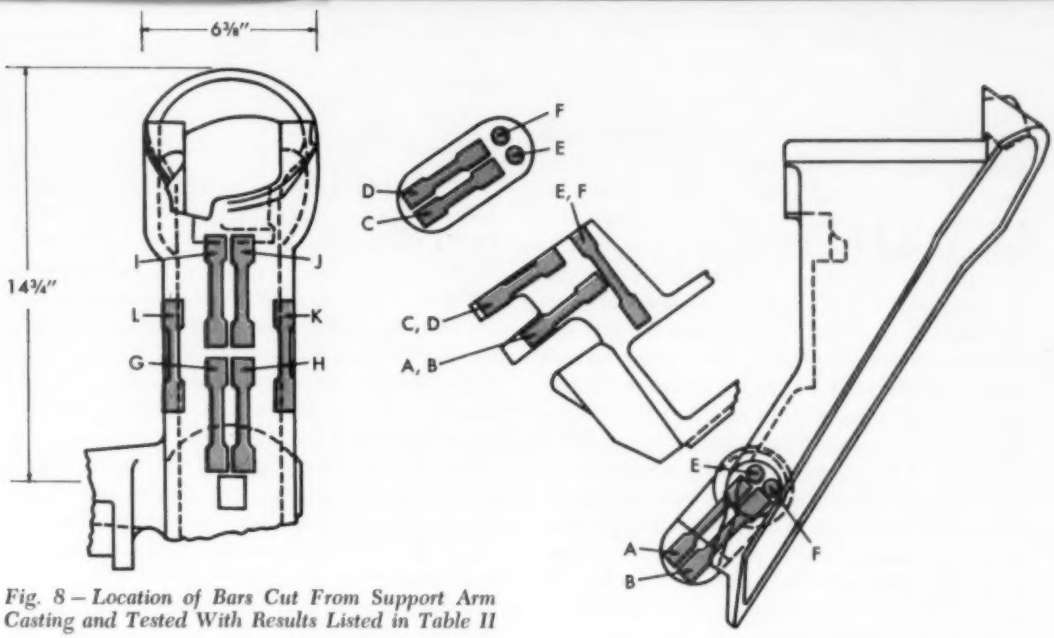


Fig. 8 – Location of Bars Cut From Support Arm Casting and Tested With Results Listed in Table II

graph of a fin casting for a missile made in A 356 alloy and heat treated to the T 6 condition. The properties obtained in the 2½-in. hub were 35,000 psi. ultimate, 21,000 psi. yield, and 13% elongation; the separately cast bars in this condition gave 36,000, 21,000 and 5%, respectively. Further aging, however, raised the strength to 45,000 psi. ultimate and 35,000 psi. yield (with 4% elongation) in the hub and 43,000, 35,000 and 2.0, respectively, in separately cast bars.

Aging times within the T 6 specification can become somewhat critical for various reasons if a certain combination of high properties is desired. Most important is that the properties are changing at a relatively rapid rate during the aging treatment. Variations in the chemical composition within the specification, variation in response to the quench due to different section thicknesses, and differences in time between the quenching and aging operations can also have significant influence on the properties.

Figure 8 shows the location of test bars, in a highly stressed support arm (Fig. 9), while Table II gives the properties obtained. This is a relatively large and complex casting with sections varying in thickness from ½ to 3 in. As can be seen from the values in the table, there is a rather wide variation in properties due to the varying sections and the amount of chilling and risering necessary to obtain a completely sound casting with the necessary high properties. These variations could be anticipated by noting the wide variations in elongation in the samples cut from test slab castings (Fig. 1).

In both of these castings, certain areas have been designated as places where the load will be concentrated. It is extremely important that such information be given to the foundry so

Fig. 9 – Photograph of Large Support Arm Casting Made of Alloy A 356 Heat Treated to T 6 Condition

proper chills can be applied and the necessary feeding gates and risers can be placed at other places receiving less stress. Many times this information will mean the difference between a successful casting and failure. It is also well to note that the request for high properties throughout a complex casting makes the job of the casting engineer extremely difficult because, first and foremost, the entire casting must be sound and completely well fed. This can be accomplished only by establishing the proper thermal gradients throughout the casting and placing liquid metal reservoirs at the slowest freezing areas. If the required high properties must be obtained in the slowest freezing areas, the entire casting must be frozen extremely rapidly, and at the same time proper gradients must be maintained so that all areas will be fed with liquid metal at the proper time. Some improvements can sometimes be made by decreasing the distance between chills and risers, but this means that more feeding connections must be made, which is not always desirable because of dimensional or surface requirements.

A request for higher properties than necessary throughout a complex casting will almost always increase the number of castings which must be made before a satisfactory one results, and therefore increases the time required to fill the order. It may be impossible to obtain the requested casting even after great expense to both the customer and the foundry, and an irreparable loss in time.

One should recognize that the properties attained from the ¾-in. slab casting do not represent the highest and lowest values attainable with A 356 alloy – or any other analysis studied in a similar manner. On thinner, more highly chilled sections of certain A 356 castings, properties of 41,000 psi. ultimate, 27,000 psi. yield, and 19% elongation have been obtained after quenching in boiling water and aging 5 hr. at 310° F. Properties given in the diagrams for the risered end of the slab probably do represent the minimum properties fairly adequately. However, it should be pointed out that the risered end of the slab is completely sound metal radiographically, with no evidence of gas porosity or shrinkage, and that it has been melted, degassed and poured into a well-designed mold of very consistent properties, after which it has been heat treated and quenched under closely controlled conditions. Unless these conditions are met, properties less than those indicated might easily result.

Summary

Alloy A 356, properly chilled and fed, has a combination of strength and ductility which fulfills the requirements of many high-quality aluminum castings. Its choice, in preference to C 355 or other similar alloys, depends on the application. Both of the alloys mentioned have excellent foundry characteristics, so that high properties can be obtained not only in simple shapes, in separately cast bars, but in complex shapes as well.

The use of a rapid quench to obtain higher mechanical properties is of questionable value in complex castings because the induced residual stresses may seriously affect satisfactory performance.

Sodium modification of A 356 alloy is of questionable value where high properties are obtained by rapid freezing. Special techniques are also needed to avoid increase in the hydrogen content. The effects of modification cannot be evaluated by separately cast bars alone.

Alloy A 356 in T 6 condition has higher elongation than C 355, particularly in the faster freezing ranges, although the strength is significantly lower. Modification of the A 356 alloy increases its elongation as compared to that of C 355 in slower freezing sections.

Variation in aging conditions can give a wide range of property combinations. Considerable variation exists even within the T 6 specification because of the relatively rapid rate at which the properties are changing during the aging treatment and the influence of small variations in the chemistry. Properties of A 356 in the T 62 condition are very similar to those obtainable using good practices with C 355 T 62.

An accurate appraisal of the type, magnitude and location of stresses which may be encountered by the casting in actual operation will be of great help to the casting engineer in working out the proper mold design and heat treating procedure. If high properties are specified throughout a complex casting when they are necessary only in certain areas, unnecessary expense and delay will be encountered in obtaining satisfactory parts.

We are now studying the causes for the variation in properties of A 356 in the modified and unmodified condition, and are evaluating other new formulations of this group containing higher amounts of the alloying elements. These studies may provide a higher combination of strength and ductility than is now attainable.

Welding Unusual Metals

*By D. W. GROBECKER**

While highly reactive metals require unusual equipment and care to prevent weld contamination, the principles of the operation are but extensions of ideas widely used to make sound joints in thin sheets of the conventional metals of commerce. (K-general; U, Zr)

It is often necessary, or at least desirable, to take advantage of the corrosion resistance and nuclear properties of many unusual metals in the design of atomic reactors and weapons. If reliable joints are to be assured in these metals, a further development of known welding processes is required, and sometimes new welding processes must be used. To exchange welding information, discuss pressing problems and compare progress, engineers from the Atomic Energy Commission contracting companies meet each year at the A.E.C. Welding Forum, with F. W. Davis of the A.E.C. Div. of Reactor Development as chairman. Ideas of interest to the entire metals industry are frequently revealed at these meetings.

The unclassified minutes of the Seventh Annual Atomic Energy Commission's Welding Conference (Nov. 6 to 8, 1957) have now been released and are available from the Office of Technical Services, Department of Commerce, Washington 25, D.C., at $2.50. These discussions stress the combined effect of careful cleaning and inert gas or vacuum to prevent contamination of the welds, automatic processes to control the weld's characteristics, and repetitive welding processes which decrease the possibility of defective welds and alleviate inspection difficulties. The sometimes brittle character of these special joints is frankly revealed; only if this is borne in mind can improper applications be avoided.

Electron Beam Welding

The electron beam vacuum welding process provides high vacuum protection from atmospheric contamination, and temperatures high enough to fuse metals of the highest melting points. E. B. LaVelle, of General Electric's Hanford Atomic Products Operation, reported that satisfactory joints can be made by electron beam welding where other joining methods are unsuitable. It has also proved superior for many of the more common joint designs. It is simple in principle, being similar to an oversized cathode ray tube. An electrical potential set up between a heated filament and the joint causes a flow of high-velocity electrons which are beamed on a small area of the joint by an electrostatic focusing gun. The elevated voltages, which can be established in the high vacuum, provide intense welding power at low amperage. The joint is rapidly heated by the energy of the impinging electrons. In fabrication operations at Hanford, a driven fixture moves the metal parts beneath the focused beam of electrons to make a continuous fused joint. Previous note of this process has been given in *Metal Progress* in May 1958, p. 65, and a fuller description in a digest of L. L. Wyman's article in *Welding Research (Metal Progress,* August 1958, p. 178).

Diffusion Bonding

The cost of the uncommon metals sometimes makes it desirable to back them up or connect them to a more common metal. Mechanical joints prove unreliable at the temperatures and pressures within a reactor. For example, extensive attempts at Knolls Atomic Power Laboratory to weld and braze the zirconium alloys

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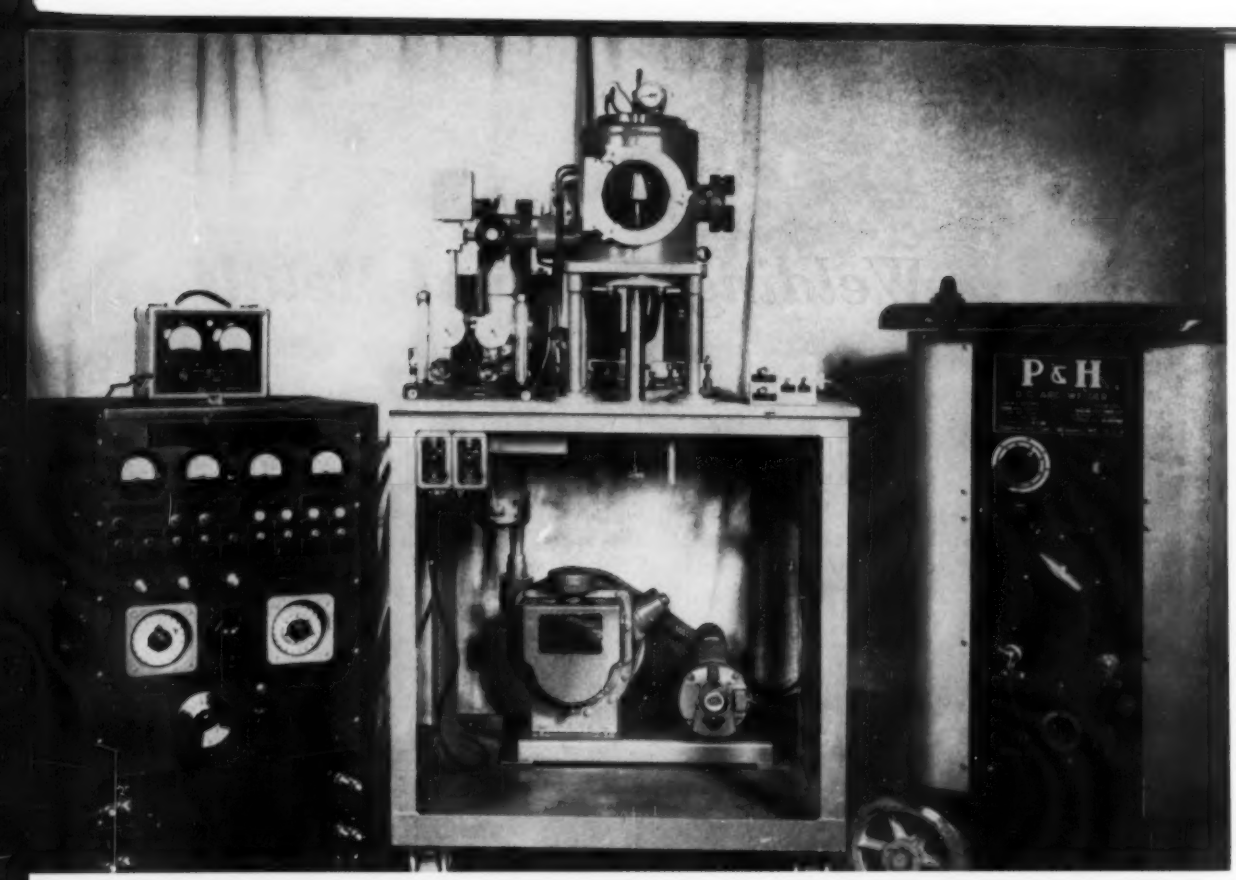

Fig. 1 — Motor-Arc Welding Apparatus Includes Source of Welding Power, Magnetic Control of Arc Motion, Vacuum Purging Equipment and Welding Chamber. (Courtesy Argonne National Laboratories)

to stainless steel resulted in very brittle joints with reduced corrosion resistance, but K. H. Koopman reported that the dissimilar metals can be bonded successfully by creating a diffusion layer between the metals.

In a certain part the zirconium and stainless steel are machined to an interference fit. The mating parts are carefully cleaned, forced together, and heated to 1800° F. under high vacuum, whereupon the abutting metals diffuse into each other. Careful design of the joints results in a bond with high shear strength, good resistance to thermal cycling, adequate corrosion resistance in hot water, and a leaktight joint under repetitive test.

Motor-Arc Welding

A new welding tool devised for the closing of small containers was reported by C. C. Stone of Argonne National Laboratory. It is known as the "motor-arc modification of the tungsten inert-gas welding method". The welding arc is moved by electronic means rather than by a mechanism. In fact the arc is moved around a tungsten electrode by the combined effect of the arc current and an especially imposed magnetic field. End closure welds in containers up to $\frac{5}{8}$ in. diameter have been successfully made by this technique, shown in Fig. 1.

Combination Welding Methods

Argonne National Laboratory has prepared many reactor fuel slugs of uranium encased in zirconium alloy. These must withstand a high temperature and a highly corrosive environment, and are fabricated by a sequence of tungsten inert-gas welding, bonding with induction heat, and spot welding. All joining operations are conducted under a protective inert gas cover. C. C. Stone reported that the fusing operations are completely automatic, primarily to insure the required quality.

Uranium rod sections which have been co-extruded with a zirconium cladding, zirconium segment separators, and zirconium end caps are thoroughly cleaned and assembled for welding. Heat is provided from a tungsten electrode, the arc impinging on the cladding. Electrode and fused metal are protected by inert gas (helium, argon or a mixture of gases) which passes through a ceramic cup surrounding the electrode. No additional weld metal is added. The fixture imposes a slight axial pressure which upsets a small amount of zirconium cladding

during fusion and provides intimate contact between the uranium core and the cladding. Weld penetration of the zirconium is limited to avoid melting any of the uranium on the inside.

The uranium core is then bonded to the case in the joint regions by inductively melting the uranium without melting the zirconium cladding. Power is selectively supplied by a single-turn induction coil.

Spacer ribs of zirconium wire are then fastened along the clad fuel slug by electric resistance spot welding. Individual spot welds are made with one electrode charged, while two other electrodes act as ground. The mechanism supplying an intermittent linear motion to the rod is coupled to a series of rotating switches so that the electrode polarity and firing sequence occur in proper relationship to the position of the rod.

Uranium Welding and Soldering

Welding of uranium is difficult because of its density, liquid fluidity, and reactivity. When oxide fumes are generated, there is also the problem of toxicity. However, successful welding of uranium in difficult shapes was reported by R. A. Noland and C. C. Stone of Argonne National Laboratory, and E. L. Brundige, J. M. Taub, G. S. Hanks and D. T. Doll of Los Alamos Scientific Laboratory.

In this work at Argonne, sheets of natural uranium enriched with the U^{235} isotope are clad with thin sheets of natural uranium. To minimize oxide entrapment and interference with the flow of fused weld metal, the cladding is carefully cleaned of black oxide by an anodic etch and light brushing. To secure an edge weld of the required quality and dimensional accuracy, special equipment was constructed. Purging, preheating and welding sequence timers, which have since become commercially available, were needed and designed. Also necessary for welding the thin uranium sheets is a sheet-holding fixture made of copper which directs an inert gas blanket over the entire assembly and includes copper molds for retaining and shaping the high-density, fluid weld metal (Fig. 2). The final edge welds present a smooth regular contour, without metallurgical defects or evidence of contamination.

Uranium cylinders with walls as thin as 0.010

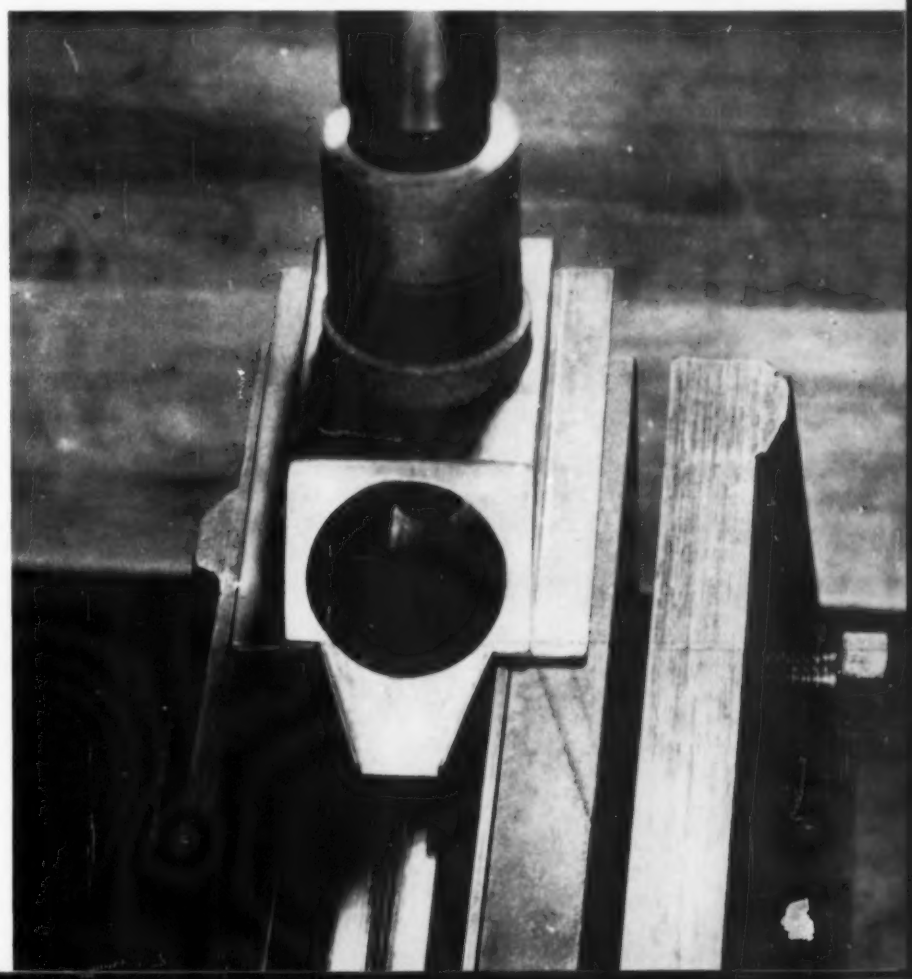

Fig. 2 – Close-Up of Uranium Edge Weld in Holding Fixture. The inert-gas welding torch comes down from above through the sliding gas shield. Copper mold sheets are shown in the channel below. In operation, the window on the gas shield is covered with a tinted glass which permits close observation of the welding arc. (Courtesy Argonne National Laboratories)

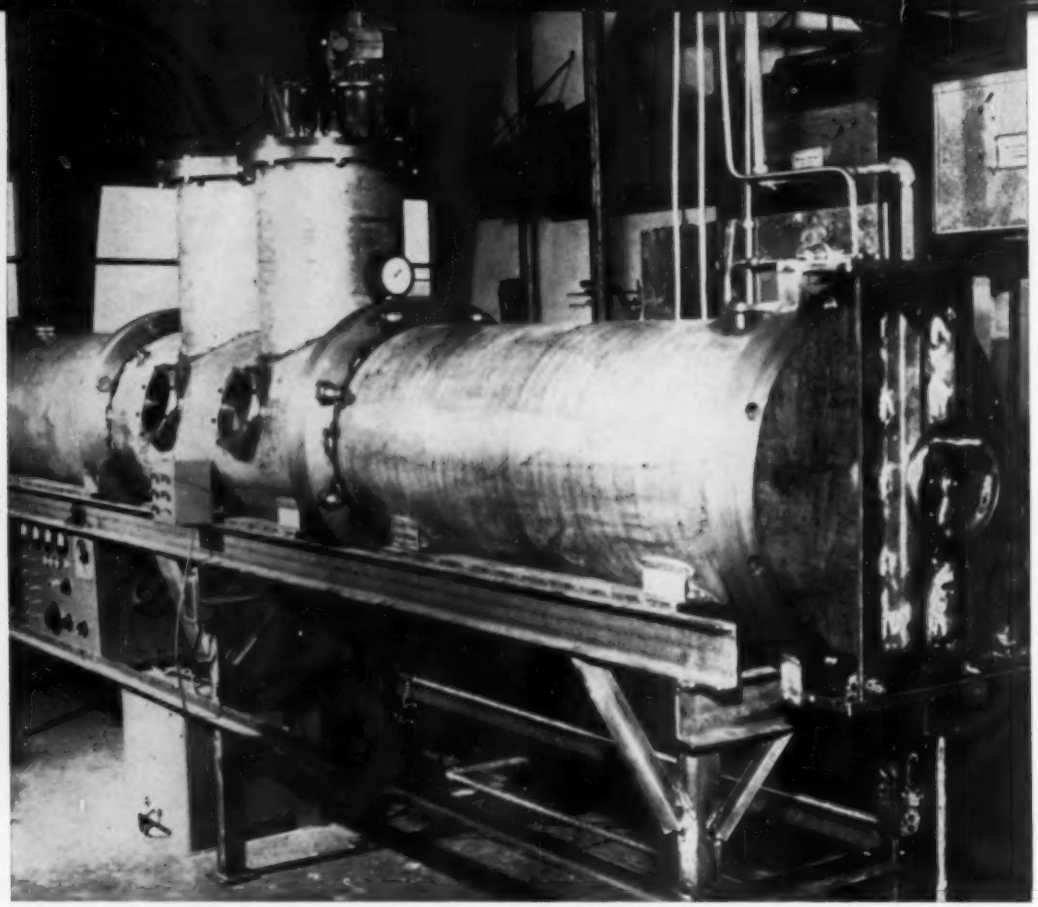

Fig. 3 – Chamber for Welding in a Protective Atmosphere. This chamber is equipped for resistance spot welding, but similar equipment may be used for fusion welding or diffusion bonding. (Courtesy Argonne National Laboratories)

in. have been fusion welded by men at Los Alamos Scientific Laboratory by the tungsten inert-gas process. For thin sheets requiring quite shallow heating, they use stabilized, high-frequency current applied through an inert gas torch. Direct current, straight polarity is preferred for heavier welds.

In welding a cylinder the part is mounted in aluminum chucks; the joints are aligned under slight pressure and moved slowly beneath the welding torch. The commercial helium and argon protective gas mixture is purified by passing it through commercial driers and then through heated uranium chips. Rather than limiting the extent of the inert-gas shielding, the entire weldment is blanketed with gas during both welding and cooling. The Los Alamos metallurgists state that uranium welds are stronger than as-cast uranium, and can subsequently be cold worked as much as 40% without cracking.

Processes for soldering uranium metal have been investigated also by G. S. Hanks, D. T. Doll, J. M. Taub and E. L. Brundige, of Los Alamos Scientific Laboratory, for applications where a low-temperature joining method is required. Although the standard lead-tin solders are unsuitable, a variety of other solders are available; pure indium, or solder containing indium, appears most desirable. A satisfactory solder-wetting method uses ultrasonics. The heated soldering iron is rapidly vibrated by an electric power transducer, causing surface shear forces in the parent metal and cavitation in the liquid solder, which combine to disrupt surface contaminants and allow intimate contact between the solder and the uranium.

Satisfactory wetting of uranium is also achieved by the loaded wheel technique, wherein the pores of an abrasive grinding wheel are loaded with solder, and the surface of the uranium is ground with the wheel. Intimate contact between solder and freshly exposed uranium (plus localized heat of frictional cutting) causes wetting or "tinning" by the solder. The solder-tinned surfaces can then be joined by conventional mild heating methods.

Early Radiophotographs

*By CLARENCE T. PATTERSON**

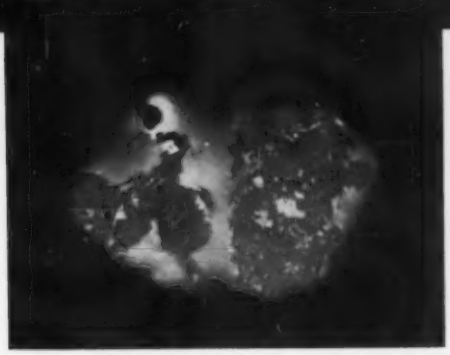

Fig. 1 – First Autoradiograph, Dated 1/7/15. Note needles of uranium-rich constituent in these pieces of high-carbon ferro-uranium

Early in 1915 the radioactivity of uranium was used to mark the position of its carbides in ferro-uranium. Intimate details of the microstructure could not be determined because these contact prints could not be magnified very highly; the "grain" of the photographic emulsion was too coarse. (A2, M23q; Fe, U, AD-n)

IN THE JUNE 1957 issue of *Metal Progress* the present author published a historical note about the manufacture of ferro-uranium and its use as an alloying element in high speed tool-steel. This work began in the fall of 1914 when I was still in Carnegie Institute of Technology.

It will also be remembered that the blackening of a photographic plate resulted in the discovery of the radioactivity of uranium by Becquerel in 1895. Just 20 years later the present author used the same principle to make uranium identify itself in ferro-uranium. Subsequently the distribution of uranium in other alloys and steels was proved by this "radiophotographic" method. I am unable to prove that the photograph reproduced in Fig. 1 and made Jan. 7, 1915, is the first autometallograph made in the United States; perhaps some readers with a bent toward history can verify or disprove that supposition.

A brief description of my methods follows:

Methods – The sample was cut or broken, ground and polished to a reasonably flat surface. The final polish could be on a wet wheel but the sample should be finished clean and dry to avoid harming the film emulsion. To minimize the effects of halation, the polished surface was carefully laid directly on the sensitive side of the photographic film in a dark room. The date, number, and sometimes an outline of the sample were noted with a lead pencil on the film for identification when several samples were exposed on the same film. (Such marks will show after developing, even when no radioactivity is apparent.)

Film and samples are then covered, lighttight, and left undisturbed long enough to produce the desired contrast on subsequent development and fixing in standard solutions. The washed and dried film was then printed with sensitive side against the paper, again to minimize halation. Uranium concentrations are shown by darkened areas on the film (or whitish areas on the positive prints).

Radiophotographs – Figure 1 is the oldest original print available. The film is dated 1/7/15. It shows two somewhat spongy pieces of ferro-uranium. The fuzzy halo is due to radiation from overhanging surfaces nearby. The bright irregular patches are due to holes in the sample. (The greater surface of a cavity per unit area of film steps up the intensity of radiation at that spot. A shallow drilling in a sound sample showed the same effect.)

Close inspection reveals a system of bright needles in definite angular grouping, locating a constituent richer in uranium than the average. Microscopic examination revealed such a structure but at that time it was not further identified.

About three years later I investigated the high-carbon ferro-uranium made by the Standard Chemical Co. by methods described in the article in June 1957. The small photo, Fig. 2, is a direct print from a 163-hr. exposure of the sample on film. Figure 3 is a six diameter enlargement from the film. The prominent white needles are easily identified by microscopic examination of the sample. They represent cross sections of platelets of uranium carbide, approxi-

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Fig. 3 – Same as Fig. 2, Enlarged Six Diameters

Fig. 2 to 4 – Macrostructure of High-Carbon Ferro-Uranium

Fig. 2 – Contact Autoradiograph; Exact Size

Fig. 4 – Optical Macrograph, 6 ×

mately UC_2. Attempts to show more detail by greater enlargement of Fig. 2 were unsatisfactory; as magnification increased, the grain of the films which were then available became more and more dominant. Above about 50× the field of view was made up of dots of variable size and number, representing the silver grains in the original film.

Figure 4 is a 6 × macrograph of the same specimen of ferro-uranium. Lighting was oblique from the top. It was also examined directly at magnifications up to 1000 ×, before and after etching. A few small needles were found in the groundmass between the large needles, but it appeared that nearly all the uranium was concentrated in the needles or platelets as carbides. Since the carbides were known to have very high melting points, this supported the hypothesis that low-carbon ferro-uranium was needed for better steelmaking.

I have in my possession numerous other films and prints of alloys under study at the time. It was found that the brightness of the print was not always proportional to the amount of uranium shown in the chemical analysis. In alloys made in the arc furnace by Standard Chemical Co. described on p. 88 of the article in June 1957 *Metal Progress*, the "element" then known as Uranium X (really a mixture of two short-life disintegration products of U^{238}, namely Th^{234} and Pa^{234}, was lost by distillation. The radioactivity of such metals would increase after aging for a few months, due to the continuous production of more "Uranium X" from the natural uranium, and the autoradiographs would then be clearer and take a shorter time.

A photograph of medium-carbon alloy containing 35.4% U published in *Metallurgical and Chemical Engineering*, Vol. 19, 1918, p. 515*, shows a fine needle-like pattern. A second one of a 7.74% U steel ingot made with low-carbon Fe-U has little or no detail, indicating uniform uranium distribution in the groundmass.

*Another historical note: The present Editor-in-Chief of *Metal Progress* was then associate editor of *Metallurgical & Chemical Engineering*.

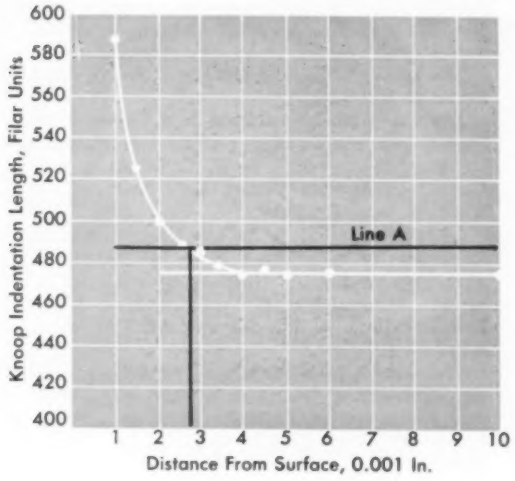
Measuring Decarburization by Microhardness

*By H. CZYZEWSKI and H. H. HONEGGER**

THE MICROHARDNESS METHOD for measurement of decarburization depth, shown in the graph, was originated when hardness tests indicated some decarburization appreciably beyond that observed by the average metallographer in a martensitic structure. The graph illustrates a typical microhardness survey of a 4130 steel sample. By using a Knoop diamond with a 200-g. load, and 50 × objective, the depth of decarburization was determined at 0.0045 in. Decarburization of 0.002 in. was reported by the metallographic method.

However, this microhardness method has some drawbacks. A difference of ± 1 filar unit in the core hardness level and in the decarburization curve will cause a variation of the intercept from 0.0035 to 0.006 in. Because of this, the results of different operators can often vary as much as ± 0.003 in. Another difficulty is that two separate specified limits for decarburization are needed since each method gives a different result.

Modified Method for Determining Decarburization by Microhardness. The white line represents the original method; the modification is shown by line A which is positioned 10 filar units above the core hardness line. The intercept point is more easily determined, and the results correspond with those obtained by metallography



Both problems were reduced by modifying the method. As shown by the black lines, the decarburization depth measured at the intercept of line A is 0.0028 in. In our method, line A represents a hardness of two Rockwell C units below the normal core hardness, and is the low limit specified for the hardness. A difference of ± 1 filar unit in the core hardness level and in the decarburization curve will cause a variation of the intercept with line A of only ± 0.0002 in. between different operators.

The revised method is based on the following factors:

1. All specifications permit a range for physical properties.
2. The specified hardness range of 4130 steel is ordinarily four Rockwell C points to allow for alloy variations.
3. When 4130 steel is used for the decarburization test, the carbon should be in the middle of the specified range.

Under these circumstances, a hardness level two Rockwell C points below the core hardness will be within the specified limit. Thus, the method consists of adjusting the core hardness for the lower level. This line (A), which represents the lower hardness, intercepts the decarburization curve at a point for which a variation of ± 1 filar unit will result in a depth variation of only ± 0.0002 in. Furthermore, the intercept at this line (A) generally conforms within 0.001 in. with the depth of decarburization reading obtained by the metallographic technique. The same specified limit can be used for both metallographic and microhardness techniques.

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Corrosion Resistance of Type 347 Stainless After "Sensitizing" Heat Treatments

By HILMER F. EBLING
and MERRILL A. SCHEIL*

Corrosion rates in boiling HNO_3 after a systematic series of long heatings between 700 and 1500° F. can be plotted in TTS (time-temperature-sensitization) diagrams so engineers can avoid fabrication practices which would produce unexpected damage from corrosive liquids. (R11, R2h; SS)

Recently there has been renewed interest in the effect of low-temperature aging on the corrosion properties of stainless steel. Principally, designers in the chemical and power industries are confronted by this problem since process temperatures are continually being pushed upward to improve efficiencies. For a long time 800° F. was considered to be the maximum for handling corrosive products in austenitic stainless vessels. The bitter experience of having costly equipment fail prematurely by intergranular attack, some 25 years ago, certainly was a good reason to be overly cautious.

Cr-Ni 18-8 austenitic stainless steels with modifications are the most widely used alloys to combat severe corrosion problems. But even with the vast amount of experience built up over the past years, costly mistakes still have been made. These alloys are susceptible to a number of different types of corrosive attack depending upon the environment to which they are exposed, among the most common being general corrosion, pitting, stress-corrosion and intergranular corrosion.

Of these, the last – the susceptibility to intergranular attack – is the only kind which is entirely influenced by the heat treatments given the metal. In other words, an alloy failing by intergranular corrosion is sure to have been exposed to a sensitizing heat treatment by the fabricator or to an improper anneal by the metal producer.

Several laboratory tests have been designed to reveal whether or not an 18-8 alloy is sensitized or susceptible to intergranular attack. These are the acidified copper sulphate test, the boiling nitric acid test, the nitric-hydrofluoric acid test, the electrolytic oxalic acid etch test, and the more recent ferric sulphate-sulphuric acid test.†

Acidified copper sulphate was the first qualitative test used in the laboratory. The boiling nitric acid or Huey test, suggested shortly thereafter, is quantitative and is extensively used as a standard. There have been many controversies over its results; many believe that it is too severe

*Mr. Ebling is research engineer in the metallurgical research department and Mr. Scheil is director of metallurgical research of A. O. Smith Corp., Milwaukee, Wis. This article is the first part of a presentation made before the U. S. Atomic Energy Commission's Welding Committee at its meeting in Richland, Wash., Oct. 13, 1958.

†For the acidified copper sulphate test see "Some Observations on Tests for Intergranular Susceptibility of 18-8 Mo Stainless Steels", by H. Ebling and M. A. Scheil, Special Technical Publication No. 93, American Society for Testing Materials (A.S.T.M.), June 30, 1949. See also A.S.T.M. Standards A 240-54 and A 393-55 T.

The boiling nitric acid test is specified in A.S.T.M. Standard A 262-55 T.

For the nitric-hydrofluoric acid test see "Accelerated Corrosion Testing of Chromium-Nickel Stainless Steel Weldments", by F. K. Bloom and M. E. Carruthers, Special Technical Publication No. 93, A.S.T.M. June 30, 1949.

The electrolytic oxalic acid etch test is described in "Screening Stainless Steels From the 240-Hr. Nitric Acid Test by Electrolytic Etching in Oxalic Acid", by M. A. Streicher, A.S.T.M. Bulletin No. 188, February 1953, p. 35. See also A.S.T.M. Standard A 262-55 T.

The test using a mixture of ferric sulphate and sulphuric acid is described in "Intergranular Corrosion Resistance of Austenitic Stainless Steels", by M. A. Streicher, A.S.T.M. Bulletin No. 229, April 1958, p. 77.

and does not represent conditions which may be found in any particular process. However, it must be remembered that these laboratory tests do not justify the use of a certain material for a particular process. All that they can reveal is whether the material under test is properly annealed, or if there has been a damaging change in metal structure during fabrication. With this in mind we justify the use of the boiling nitric acid test at A. O. Smith Corp.

It is claimed that the acidified copper sulphate test and the new ferric sulphate-sulphuric acid test reveal sensitization of metal only if chromium carbides are precipitated on the grain boundaries. The boiling nitric acid test, on the other hand, reveals sensitization of metal when either chromium carbides or the sigma phase (or both) are precipitated; thus, it shows grain-boundary weakness regardless of cause. This then fulfills the primary purpose of the test. Whether or not this attack would occur in service is not always known. However, if such attack does occur in service, the fabricator would be in an embarrassing position since he knowingly used heat treatments which greatly reduced the original corrosion resistance of the material.

Some chemical processes can attack metal which is apparently sensitized by precipitation of the sigma phase. If this were not true, Type 316 L material should practically never fail in service by intergranular corrosion. We have not found any sensitized 316 L resulting from normal fabricating heat treatments when tested in acidified copper sulphate. However, some of the same heat treatments would produce badly sensitized material when appraised by boiling nitric acid. Since we know that Type 316 *can* fail by intergranular corrosion in service, we have to conclude that the boiling nitric acid test is the proper one to reveal susceptibility to intergranular attack.

The 18-8 stainless steels are, strictly speaking, unstable in the mill-annealed condition principally because the austenite is supersaturated with carbon; however, it is in this very condition that susceptibility to intergranular corrosion is at the minimum. Unfortunately, this condition is easily upset by welding, hot forming, stress-relieving or high-temperature service. To overcome this deficiency, carbide stabilizers were added, or the carbon lowered to 0.03% max. With these improvements in analysis articles can now be fabricated easily without upsetting the metal's original corrosion resistance to any great extent due to carbide precipitation. Unfortunately even then the materials remain structurally unstable and produce another source of trouble, namely formation of sigma phase at the grain boundaries which occurs in the same temperature range in which the carbide precipitates. Sigma precipitation produces a similar chromium deficiency in its adjacent area, except to a lesser degree. The nitric acid test is sensitive to this chromium deficiency, while the other tests apparently are not.

From what has been said above, it should be apparent that time and temperature – the time spent at a temperature within the sensitizing range – are the factors for the annealer and fabricator to watch. It appears, however, that this combination has not been too well explored. It is consequently the purpose of this paper to show the effect of aging Type 347 stainless steel for various lengths of time on its nitric acid corrosion resistance. In a subsequent paper Types 304 L and 316 L will be similarly examined.

Test Procedure

All the metal used in these tests was from commercial sheet, 12-gage (0.109 in.) received in the mill-annealed condition, pickled and furnished with a 2 D finish. Coupons approximately 2 × 3 in. in size were cut from each time-temperature exposure. A corrosion specimen approximately 1 × 2 in. was then cut off the sample, and the remainder saved for a duplicate specimen, if necessary, for microscopy, or for other tests which might be suggested later. All the corrosion specimens were prepared in accordance with A.S.T.M. specification A 262-55 T. All specimens were immersed in the acid for five 48-hr. periods, except when the corrosion rates exceeded 1 ipy. (inch per year).

Type 347 Stainless

About 20 years ago the first heats of Type 347 stainless steel were made commercially. This 18-8 Cr-Ni alloy had a columbium addition which supposedly "stabilized" the carbon, thus preventing carbide precipitation and intergranular attack by corrosive agents. The amount of columbium necessary to do this was 8 to 10 times the carbon content. Laboratory tests, particularly the acidified copper sulphate test, indicated that this stabilized austenitic stainless steel was now immune to intergranular attack regardless of the heat treatment. This viewpoint is still held by many metallurgists.

In the investigation now being reported, two

heats of Type 347 were selected from different producers. Analyses follow:

	Heat A	Heat B
Carbon	0.07	0.08
Manganese	1.50	1.28
Phosphorus	0.031	0.020
Sulphur	0.008	0.022
Silicon	0.38	0.41
Chromium	18.41	18.30
Nickel	11.75	10.72
Columbium	0.81	0.77
Nitrogen	0.050	0.030

Originally it was planned to explore the effect of reheating temperatures in 100° F. increments from 700 to 1000° F.; however, the results were so interesting that it was practically mandatory to extend the temperature to 1500° F. in order to satisfy our curiosity. Although the tests on material reheated to the higher temperatures for long time have not been completed, the time-temperatur relationships do show definite trends.

From Table I it can be noted that Heat A has very high corrosion rates when tested after heating 1000 hr. or more at 900° F., 100 hr. or more at 1000° F. and after 35 hr. or more at 1100° F. The corrosion rate rapidly decreases for the samples heated 10,000 hr. at 1000° F.

If these data are plotted as temperature-contour curves, the family shown in Fig. 1 results, and it is seen that the highest corrosion rates result from sensitizing at the lower temperatures 900 to 1100° F., although it takes a long time at temperature to reach the maximum (1000 hr. or more).

If the data are replotted, making time-contour curves, Fig. 2 results. This puts the effect of the temperature and time on the corrosion rate in a different light. In addition, the effect of intermediate temperatures can be interpolated. By taking the time-temperature relationship at any particular corrosion rate, a graph can be constructed showing the contours of various corrosion levels as a function of time and temperature.

Such a diagram is shown in Fig. 3. The data are now in a form in which the time-temperature relationship is easily seen for producing a particular corrosion rate. This graph is somewhat the same as the familiar TTT (time-temperature-transformation) diagrams. This graph could be called a TTS (time-temperature-sensitization) diagram for a wrought stainless, Type 347. The broken lines indicate that we have no data to confirm these portions of the curves.

From this diagram the corrosion rate resulting from any simple heat treatment can be predicted. With a little more exploratory work in the short times of heating, we can determine the minimum cooling rate to produce properly annealed material. When some samples are heated (aged) at the longer times and given corrosion tests, the time and temperature which might result in permanent stabilization will be known. The time indicated in the tables and graphs is the cumulative time at the indicated temperature; thus, the condition of 1000° F. for 1000 hr. does not mean that the 1000 hr. is one heat treatment; it could be ten 100-hr. treatments.

The corrosion resistance of Type 347 can be greatly increased, at least for the two heats involved in these tests, by intermediate heating to 1650° F., and holding for 2 hr. These sheet specimens were cooled at a rate equivalent to air cooling a ¾-in. thick plate by placing them between 0.5 and 0.25-in. stainless plates throughout the heat treating procedure. This treatment is sometimes referred to as a "stabilization heat treatment" and it certainly proved to be of value in these tests.

The corrosion rates of samples of Heat A given this stabilization heat treatment prior to aging at elevated temperatures are shown in Fig. 4. As far as the tests go, the corrosion rates are in the order of one tenth that observed for the highly sensitized conditions of the mill-annealed sheet.

(Continued beyond Data Sheet)

Table I — Nitric Acid Corrosion of Type 347 Stainless, Heat A, in In. per Year

Time, Hr.	Temperature, °F.								
	700	800	900	1000	1100	1200	1300	1400	1500
0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1	—	—	—	—	—	0.015	0.023	0.019	0.011
3.5	—	—	—	—	0.009	0.027	0.034	0.019	0.010
10	—	—	—	0.008	0.026	0.054	0.039	0.018	0.009
35	—	—	—	0.022	0.112	0.085	0.027	0.014	0.012
100	0.011	0.008	0.008	0.055	0.181	0.062	0.026	0.012	0.008
350	—	—	0.010	0.218	0.290	0.058	0.025		
1000	—	—	0.042	0.495					
3500	0.007	0.008	0.335	0.516					
10,000	0.006	0.010	1.114*	0.097					

*Discontinued after second 48-hr. period in boiling HNO_3; rate is computed for last period of test (others are average for the five 48-hr. periods).

One of the 42 studs that hold the Shippingport* reactor's top head to its shell section...

This stud must not fail... that's why it's 4340 Nickel Alloy Steel

Forty-two studs, just like the one shown above, are being used to fasten a nuclear reactor's top head to its shell section.

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In nuclear reactors as studs, or in steel mills as heavy-duty gears, or in rotary shears as shafts 4340 Nickel alloy steel proves again and again that it gives the best combination of strength, toughness, ductility, and resistance to fatigue. Performance proves that 4340 gives the properties which are best suited for moderate-to-heavy section parts.

Performance on these jobs also proves that AISI 4340 responds reliably to all forms of heat treatment. In the stud shown above, for example, 4340's ability to be hardened easily throughout large sections was of tremendous value. And its ability to be machined *after* heat treatment was valuable in thread cutting.

The high hardenability of this Nickel alloy steel, its machinability as heat treated up to 340 BHN, can prove valuable to you, too.

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*Shippingport Nuclear Power Station. Operated by Duquesne Light Company. Designed by Westinghouse Electric Corporation. Reactor Vessel designed and manufactured by Combustion Engineering, Inc.

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NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Time-Temperature-Sensitization Diagrams for Type 347 Stainless

By HILMER F. EBLING and MERRILL A. SCHEIL

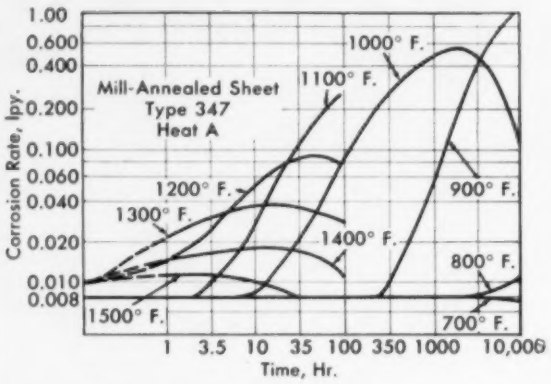

Fig. 1 — Log-Log Plot of Temperature-Contour Curves Showing Corrosion Rates of Type 347 Stainless (Heat A) Sensitized 1 to 10,000 Hr. at 700 to 1500° F.

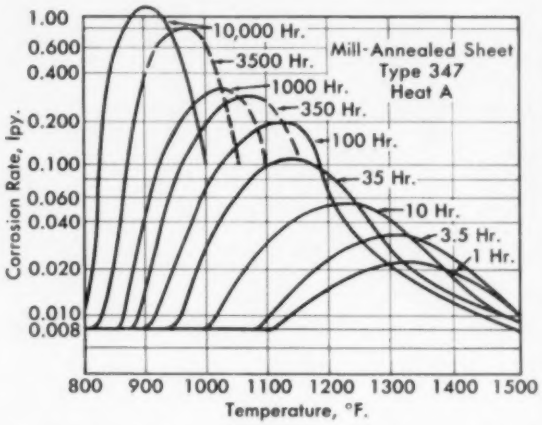

Fig. 2 — Time-Contour Curves Showing Corrosion Rates After Sensitizing for Given Times and Temperatures

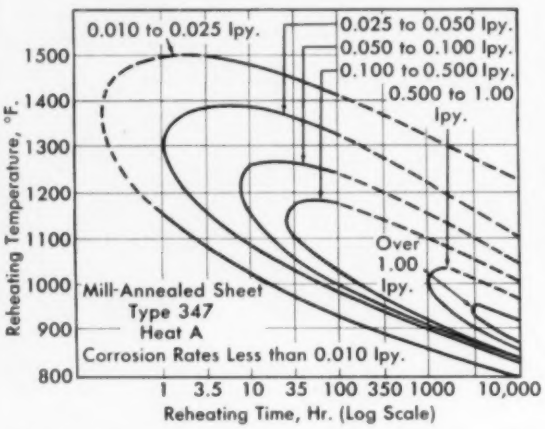

Fig. 3 — Time-Temperature-Sensitization Diagram for Mill-Annealed Type 347 Sheet (Heat A). Sensitization measured by corrosion rates in Huey test (boiling HNO_3)

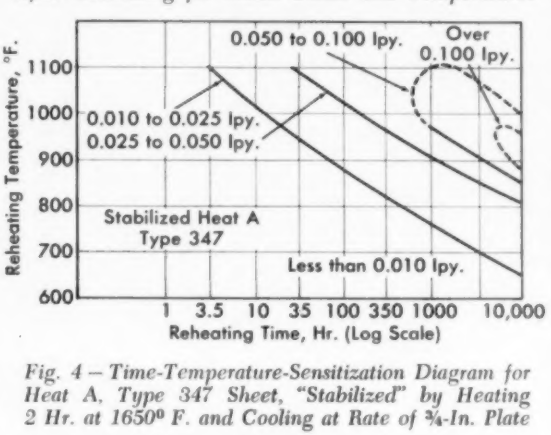

Fig. 4 — Time-Temperature-Sensitization Diagram for Heat A, Type 347 Sheet, "Stabilized" by Heating 2 Hr. at 1650° F. and Cooling at Rate of ¾-In. Plate

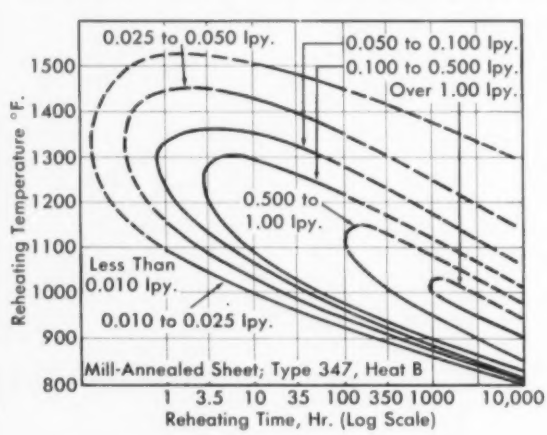

Fig. 5 — Time-Temperature-Sensitization Diagram for Mill-Annealed Type 347 Sheet (Heat B)

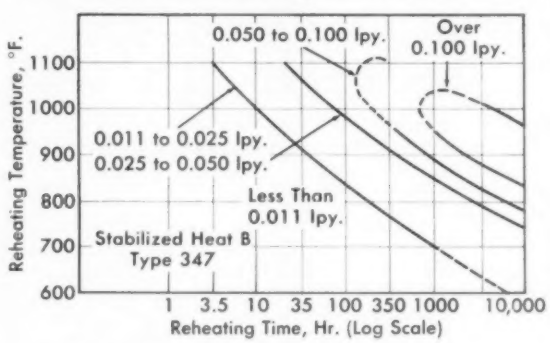

Fig. 6 — TTS Diagram for Heat B, Type 347 Sheet, Reheated After "Stabilization" for 2 Hr. at 1650° F.

	Heat A	Heat B		Heat A	Heat B
C	0.07	0.08	Cr	18.41	18.30
Mn	1.50	1.28	Ni	11.75	10.72
P	0.031	0.020	Cb	0.81	0.77
S	0.008	0.022	N	0.050	0.030
Si	0.38	0.41			

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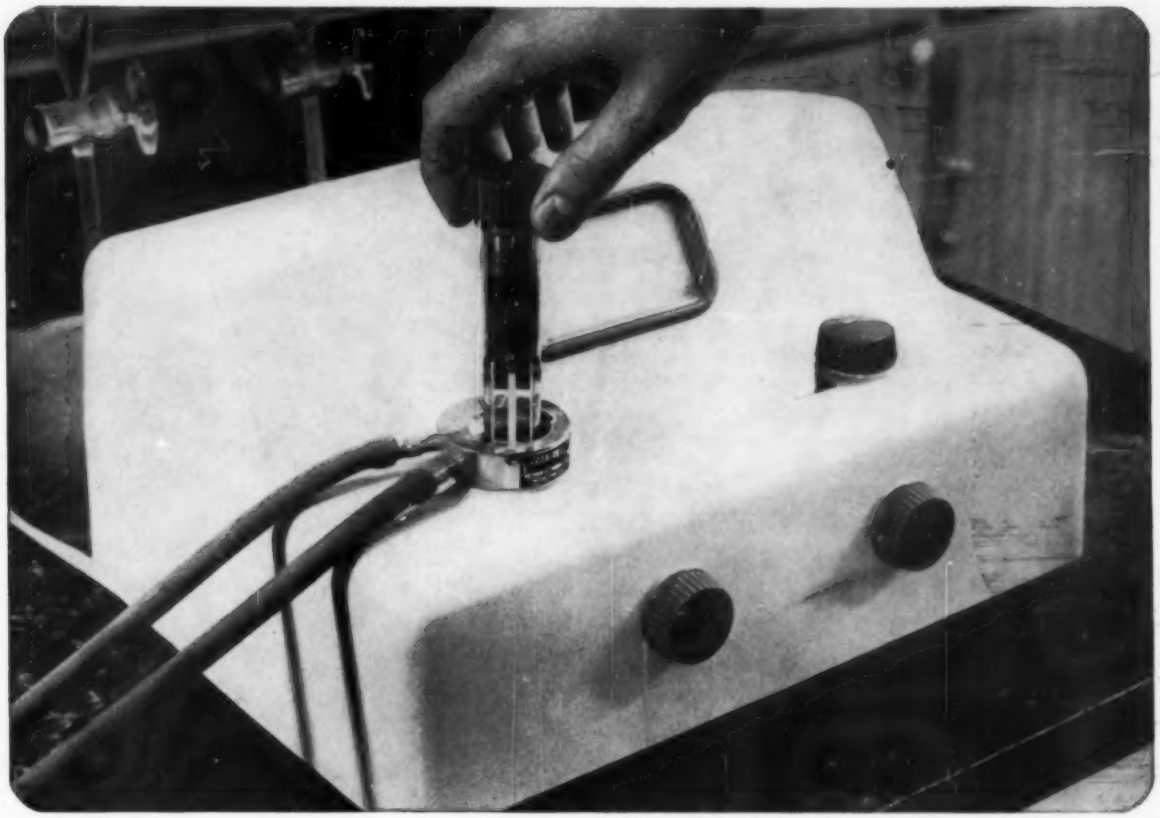

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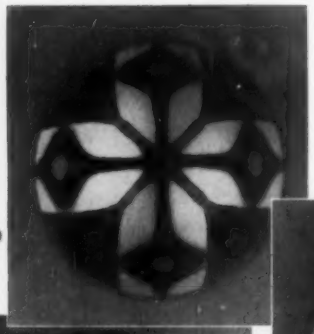

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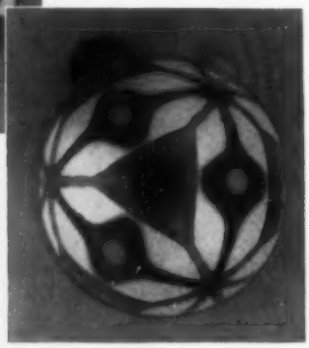

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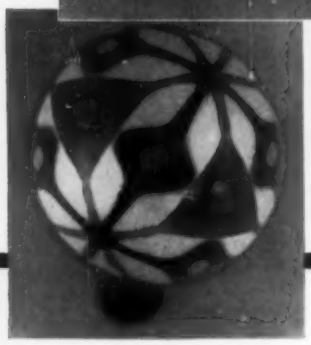

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LUCAS AWARD WINNERS for the best entry in the *Color Print* class and in the exhibit—Messrs. Denny, Epperson, Gower, Gray and Griggs, Oak Ridge National Laboratory, Union Carbide Nuclear Co., Metallurgy Division, Oak Ridge, Tenn.

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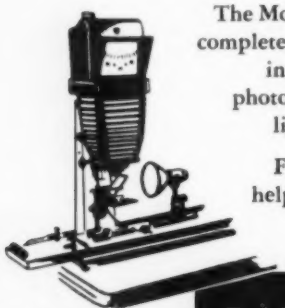

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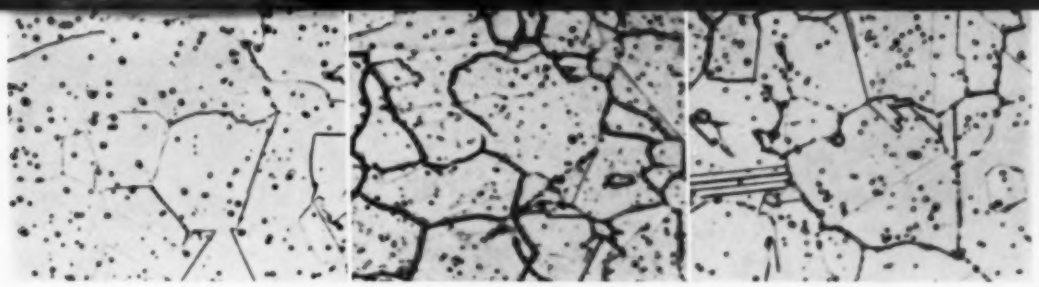


Stabilized (1650° F., 2 hr.) 0.009 ipy. *Sensitized (1000° F., 3500 hr.) 0.516 ipy.* *Sensitized (1000° F., 10,000 hr.) 0.097 ipy.*

Fig. 7 – Microstructure, Heat Treatment and Corrosion Rates of Type 347 Stainless Steel (Heat A). Etchant – aqua regia and cupric chloride. 1000 ×

Data for Heat B – Heat B of Type 347 was tested in a similar manner. From the chemical analysis previously quoted it would appear that the principal variations from Heat A are in the carbon-to-columbium ratios, lower nickel, manganese and nitrogen and higher sulphur. Its TTS diagram is shown in Fig. 5, and comparison with the analogous chart for Heat A (Fig. 3) shows that the corrosion rate levels are pushed to the left, indicating a higher susceptibility to intergranular attack.

As shown in Fig. 6, in comparison with Fig. 5, Heat B was also greatly benefited by the stabilizing heat treatment prior to aging, a matter most evident after the stabilized sheet was aged at 1100° F. Corrosion rates after 35 to 350 hr. at 1100° F. were about one-tenth those of similar specimens from annealed stock, not stabilized (Fig. 5). The high corrosion rates after long heatings at 900 and 1000° F. were also greatly reduced. Comparing Heat B with Heat A, both in stabilized condition (Fig. 6 versus Fig. 4), it will be seen that Heat B is the more susceptible to intergranular attack even after being "stabilized" for 2 hr. at 1650° F.

Microstructure – Selected specimens of both heats were examined microscopically. There were no apparent differences between the annealed stock and the stabilized stock. Figure 7 shows microstructures of Heat A. At the left is the stabilized (1650° F., 2 hr.) condition, and it may be noted that the grain boundaries are not as well delineated by the etchant as are the twinning lines. The corrosion rate obtained on this structure is less than 0.010 ipy.

The center micro represents the aged condition of 1000° F. for 3500 hr. Here is seen a heavily attacked grain boundary which is a typical example of sensitized material. Its corrosion rate is over 0.5 ipy. The structure at the right represents the aged condition of 1000° F. for 10,000 hr.; the grain boundaries are delineated but not badly attacked and the corrosion rate is less than 0.1 ipy.

The intergranular weakness, shown by the corrosion rates and the microstructure, is primarily due to carbide precipitation. There is some indication that this is not the only cause, but it could be accompanied by sigma formation which also competes for chromium in the adjacent areas. The recovery of corrosion resistance after longer heatings may be attributed to the fact that all the supersaturated carbon and some sigma phase has had time to be precipitated and chromium is diffusing from the adjacent areas into the badly depleted areas at the boundaries. If this occurs in all commercial heats of Type 347, we have a self-healing process which may permit us to truly stabilize the material.

Conclusion

By looking over the magnitude of the corrosion rates obtained after some of the heat treatments, it appears that Type 347 material is not wholly stabilized and far from immune to intergranular attack. However, Type 347 wrought material, under certain conditions, is the most resistant of the 18-8 austenitic materials as far as intergranular attack is concerned. The TTS diagrams given here may enable the metals engineer to control the heat treatment so as to avoid unexpectedly high rates of corrosion.

We have so far studied only two commercial heats, yet we find striking parallelisms in the results. If, through a lot more experience, all Type 347 wrought materials are found to follow this pattern, perhaps a "sensitivity factor" can be computed from the chemistry of the heat which would serve as a benchmark to construct a TTS diagram for that particular material. If a sensitivity factor cannot be obtained by the chemistry, two or three corrosion tests could be made and the results of these tests would serve as benchmarks to fill in the rest of the diagram. At any rate, there are not enough data at present to establish general rules of this sort.

In a subsequent article we will give similar information on Type 304 L (low-carbon 18-8) and Type 316 L (low-carbon 18-12-3 Cr-Ni-Mo).

Descaling Wire Rods by Shot-Blast

*By K. J. SORACE**

A continuous line for drawing wire at 300 ft. per min. depends on a shot-blast method for descaling. Costs are comparable to conventional methods, and the pollution problem (from acid pickling baths) is avoided. (L10c, F28, I-61; ST)

ANY PROCESS that is truly *continuous* combines a series of related operations, each of which is performed in turn. Furthermore, the speed of any one operation is the same as all others. There is no shipment to storage and return to processing unless this, too, is continuous. These are stiff requirements, but after several years of development, shot-blast cleaning and drawing of wire rods has reached this point. Today, hot rolled wire rods are descaled, coated with phosphate and drawn into cold heading wire in one continuous operation. Speeds are comparable to those in most wire mills. The steps we followed to reach this point are given in this article.

Limitations of Conventional Processes

Wire rods have been pickled in acid for 100 years; this has been, in fact, the preferred method for descaling. The basic method employed today differs little from the original. True, we have progressed from wooden vats to rubber-lined steel tanks and acid brick linings, gantry cranes, submerged combustion, inhibitors, foam blankets, spray rinse tanks, dehydrated lime, phosphate coatings and flash bakers, but the pickle line of today is still a pickle line. Perhaps, we might say, a Model "T" with chrome trim and a supercharger.

Disposal of the waste pickle liquor, which contains sulphuric acid and ferrous sulphate, has plagued user and municipality alike. The waste pollutes rivers and streams, kills fish and game, and gives sewage disposal plants headaches. Many governments have banned its disposal without neutralization, and have required neutralization to a point where contamination was not a problem. *Any* neutralization costs money; acid regeneration equipment and labor to operate it are also costly.

Our problem was, therefore, to replace the acid pickle with another descaling method, one that would do a comparable job at similar costs.

After looking into the situation, we decided to investigate mechanical descaling. Of the many available mechanical methods (and combination methods which included pickling), we chose shot-blasting as the most practical for our purpose. Since 1953, we have been developing a continuous method for shot-blast cleaning and drawing of wire rods.

How the Process Works

Drawn wire normally requires a lubricant coating for extrusion and cold forming in solid or closed dies. In any continuous line, there must be provisions for coating and drawing as well as descaling. Let us investigate such a line as now set up.

First, we need a suitable payoff reel. A unit of the "flipper" type is preferred, since coil ends must be welded to produce a continuous strand. Wire passes the usual "snarl switch"† installed

*Superintendent of Originating, Lamson & Sessions Co., Cleveland.

†A lever controlling the motors which moves when hit by a snarl of wire from the payoff reel. This shuts the line down.

to protect the equipment. It then enters a "drag" unit which straightens minor kinks and insures smooth, straight passage of the rod through the rest of the line. From there, it passes through the shot-blasting cabinet; this is fully lined with abrasive resistant plates, and has three blasting wheels placed at 120° intervals around the passing strand. Pulleys arranged around the cabinet guide the wire through the shot-blasting cabinet twice for thorough cleaning. Coating with Bonderite, neutralizing and drawing complete the process.

Specifications for the equipment (which operates at 300 ft. per min. and coats the wire with 500+ mg. per sq.ft. of phosphate) follow:

Shot-Blasting Unit – Three 20-hp. wheel motors driving 19-in. diameter wheels with blades 1⅝ in. wide.

Shot Size – Mixture of 0.007 and 0.011-in. diameter hardened steel shot (about Rockwell C-45).

Shot Consumption – About 50 lb. per 4 hr. blasting time.

Rod Size – 7/32 to ½ in. diameter; two passes through shot-blast cabinet.

Bonderite Coating Time – 15 sec. minimum.

Drawing Lubricant – Aluminum or calcium stearate mixed with lime.

In the early phases, a hot lime slurry was used for coating. At first, drying was a problem, but was solved by high-pressure line burners in a drying tunnel. An air blast cooling tunnel was also installed ahead of the draw block. Although drawing was accomplished, these coatings were not entirely suitable for fastener manufacture. Baths of rapid-coating phosphate solved this problem but added many feet to the line for the required 15-sec. immersion. Turn-around sheaves which passed the strand through the solution several times solved this difficulty.

Unlike the coating problem, changing wire sizes proved very simple; one rod was merely welded to the next. With a roll or swage pointer at the draw block end, it is only necessary to cut the strand at the weld, point it and start it through the new drawing dies.

Control of the coating bath is not difficult, though it requires daily checks and additions of replenishing chemical. The bath is heated by an electrode steam boiler in conjunction with platecoils of electropolished stainless steel. Steam rinses and air blowoff knives reduce drag-out and prevent contamination of the neutralizing rinse.

Shot-blasting produces a uniform matte finish which seems to be ideal for trapping lubricant ahead of the drawing operation. The phosphate coating takes very well on the rod and absorbs

Fig. 1 – Continuous Wiredrawing Unit. Wire travels from the reel at the left through a straightener (not shown) and into the shot-blasting unit in the rear. Coating and drawing complete the operation

Fig. 2 – Here, Wire Leaves the Straightener and Travels Across to the Shot-Blasting Unit at the Left. Production is 300 ft. per min.

enough lubricant for further extrusion. Reduction in area of 15 to 30% will smooth the indentations in low-carbon wire and produce a good finish. Though shot-blasting produces a slight surface hardening (to a depth of several thousandths), it is not detrimental in our work.

Development Took Six Years

Perhaps all this sounds too simple to be considered a revolutionary development. We are, however, describing the present conclusion of almost six years of work. Shortly after we started, it was obvious that wire could be cleaned in production by mechanical descaling, but wire that would meet our specifications was another story.

Maintenance of equipment was also an unknown factor, although the manufacturer estimated it to be about 50¢ per blasting hour. This figure has not yet been verified; we are only to 1800 hr. of blasting maximum and have not spent the $900 this figure would allow. With the increasing age of the units, it is quite possible that this cost will catch up to us.

We feel that preventive maintenance is a must, since the equipment is cannibalistic by nature. Although the shot-blasting cabinet is fully lined with hard manganese steel plates, regular inspection and routine replacement of worn parts are essential.

We have played host to many wire men from the United States, Canada, Germany, Switzerland, England, France, Japan and several other countries. With this widespread group evaluating the process, it appears reasonable to assume that it may find applications in many fields. Suggested uses include production of fence wire, coat hanger wire, tire bead wire, steel cable strands, toolsteel wire, and large-diameter bar stock in coils, as well as the fastener wire we are producing.

This cleaning method can be combined with various coating baths in conjunction with drawing and forming equipment. By proper sizing of the cleaning units and coating sections, any degree of cleanliness and speed of operation can be made workable. For example, 18 strands are cleaned at one time by equipment now in use in a patenting furnace line. Strand quantity is merely a function of the blast pattern; it must be fitted to the job. Speed is obtained by increasing the time of exposure to the blast. We are averaging 2500 lb. of wire per blasting hour in the ¼, 5/16 and ⅜-in. range, but this can be much higher when material of larger diameter is processed.

It may be that a corner has been turned, now that continuous shot-blast cleaning and drawing of wire rods is practical. It should find its place in the continuing development of new and better methods of wire production.

Sulphur Printing . . . a New Evaluation

*By S. RAMACHANDRAN and W. G. RENSHAW**

Normally quite accurate in outlining sulphide distribution in steels, sulphur prints can be adversely affected by tiny electrical currents generated between inclusion and base metal. The misleading indications which occur are explained by corrosion theory. (M23, 9-69; ST)

METALLURGISTS who depend on sulphur prints to illustrate sulphide dispersion in steels are warned to study their results carefully. On occasion, erratic electrochemical reactions between metal and sulphide can mislead the scientist and result in false interpretations. Consequently, supplemental experimentation is often needed to establish the validity of the results obtained in sulphur printing.

Preliminaries

Sulphur printing is a familiar test to the ferrous metallurgist. It is simple, requiring only unexposed glossy photographic printing paper and a 2% solution of sulphuric acid in water. To obtain the print, the paper is soaked in the acid and pressed firmly against the polished sample. Sulphide distribution is shown as brown spots on the paper which are formed by action of hydrogen sulphide liberated during reaction of sulphides with acid.

The test has become standard through the years, and its results have generally been confirmed by subsequent examinations. Like all other test methods, however, it is not foolproof. There have been instances in which sulphur print results were not confirmed by later testing. Until now, these anomalies have not been explained. Consequently, when we met with similar difficulties during routine examination of a high-sulphur toolsteel, we decided to investigate further.

Experimental Work

The steel billet used for experiment had the following composition: 0.83 C, 0.23 Mn, 0.020 P, 0.12 S, 0.28 Si, 1.69 W, 3.87 Cr, 1.09 V, 0.12 Ni, 8.66 Mo. A cross section was cut and a sulphur print prepared. As shown in Fig. 1, a high degree of sulphide segregation was indicated, although chemical analyses at different areas did not reveal any significant variation in sulphur content. The average metallurgist would logically interpret the dark spots on the print to represent sulphide particles concentrated much more heavily near the billet surface. Macroetching of the specimen showed this conclusion to be in error. Inclusions were uniformly distributed (Fig. 2), but larger at the center than near the surface. (Such an inclusion size varia-

*Research Laboratory, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

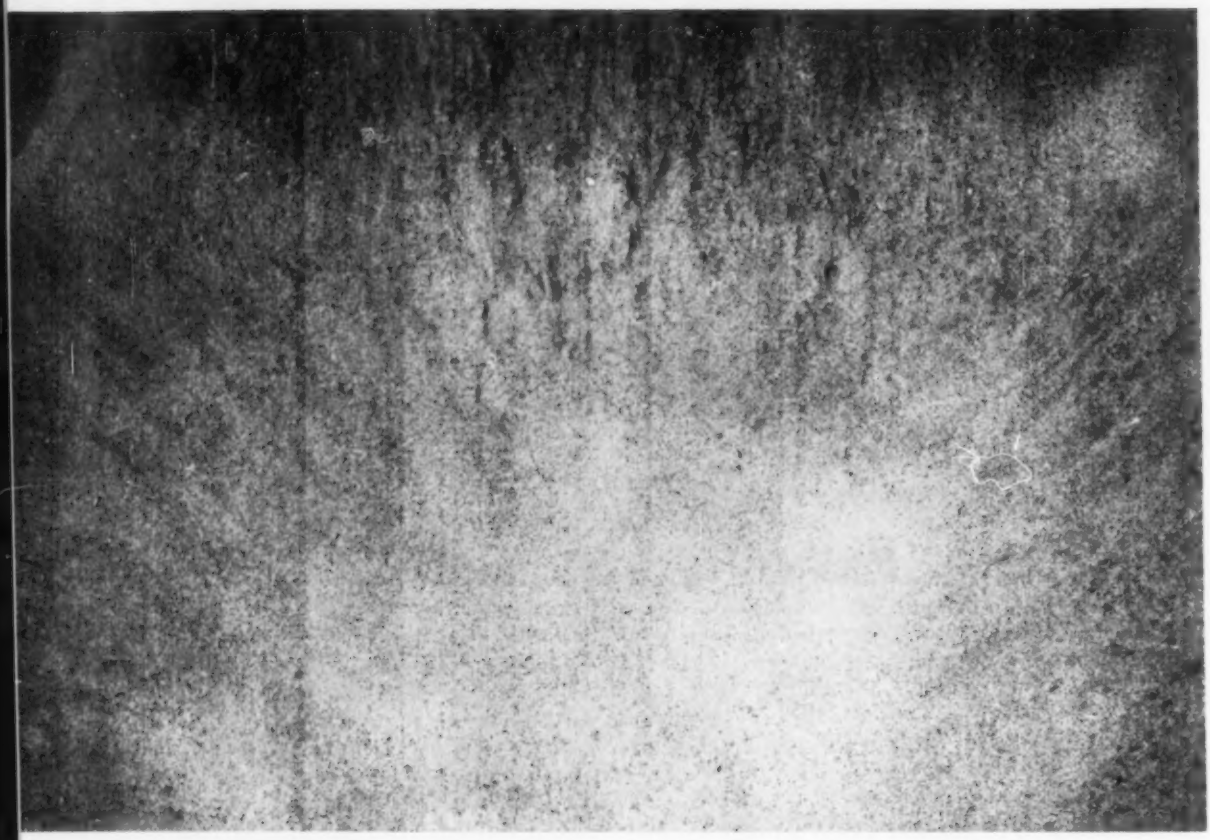


Fig. 1 – Sulphur Print of Transverse Slice. Approximately half the slice is shown; the ingot edge is at the top, the ingot center at the bottom. Note heavy sulphide indications around the edge

tion is normal in an ingot; it is caused by fast freezing at the surface and slow freezing in the center.)

We continued the investigation by examining specimens from both center and surface (with a microscope), and proved that sulphide inclusions were present throughout the billet, but that only large sulphide particles existed at the center.

Further Work

We were convinced, of course, that the sulphur prints were erroneous because their information was contradicted by chemical analyses, macro-etching and microscopic examination. Therefore, the prints were more closely scrutinized. It appeared that only the small inclusions were developed by sulphur printing while large particles did not produce an effect. This would be in direct opposition to any behavior predicted by chemical attack, but a logical explanation could be deduced by electrochemical theory.

Essentially, the problem is one of attack or corrosion of a metal by a dilute acid. Generally, corrosion can be considered to be electrochemical. Here, a local corrosion cell can be imagined with the sulphide inclusion as the anode, the base metal as the cathode and the acid as the electrolyte. As the anode corrodes, hydrogen sulphide is released; this gas does the printing. In the proposed cell, the anode areas are very small in comparison with the cathode areas, and the total current is largely controlled by the cathode. The anodic current density will be a sensitive function of the anodic area; it increases sharply as the anode area is decreased. In any electrochemical reaction, high current density will result in a high rate of anode dissolution. In other words, smaller inclusions are attacked more severely than the large inclusions. The low rate of attack of the larger sulphides is not sufficient to affect the photographic paper, and anomalous results are obtained.

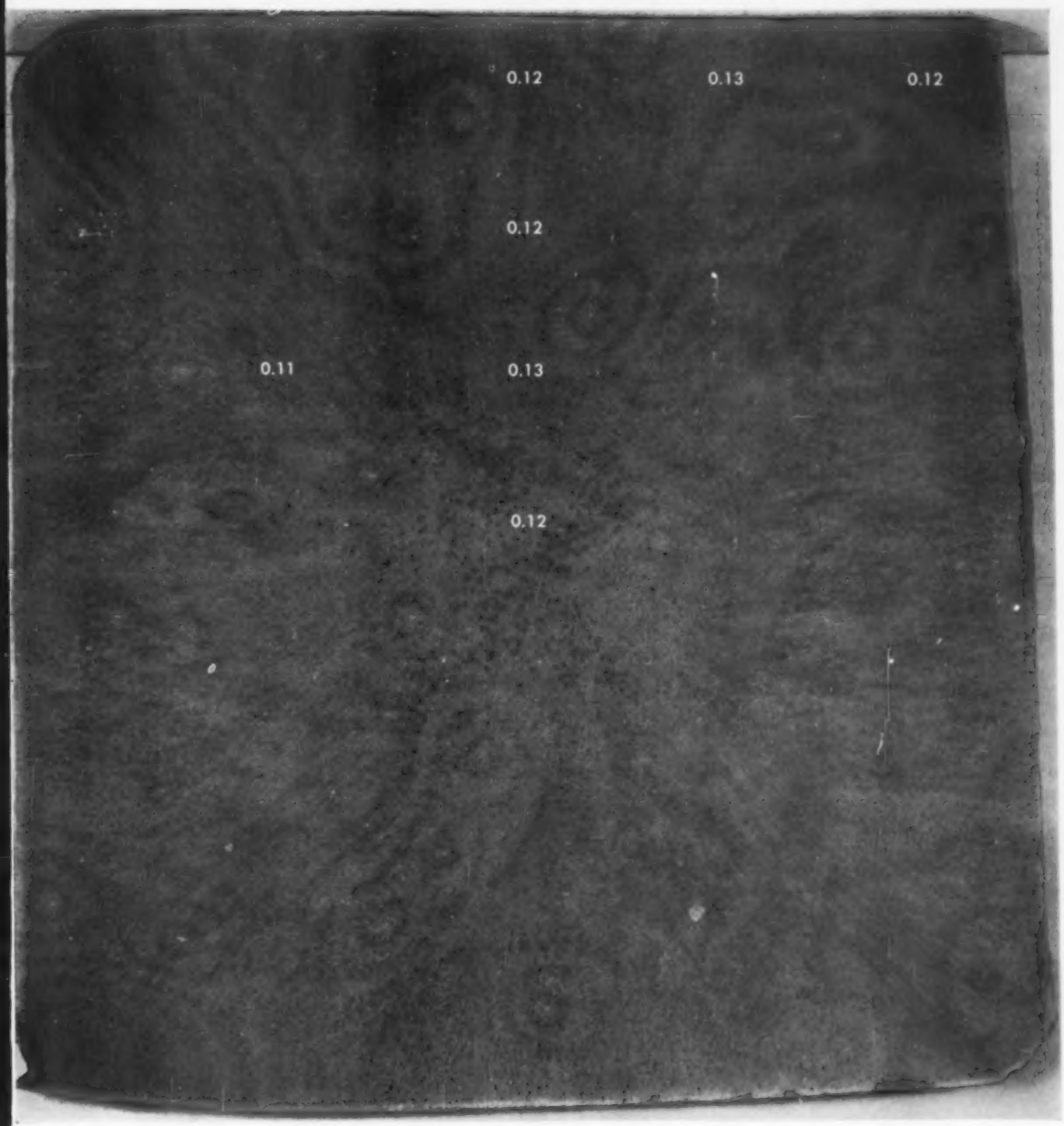


Fig. 2—Macro-Etch Test of Transverse Slice From Ingot. This test and the listed analyses show the sulphur print indications to be erroneous. Here, sulphur distribution is even and larger sulphides are in the central zone

To substantiate this explanation, the currents between anodic inclusions with different areas and a surrounding metallic cathode were measured and found to be equal. To measure the currents involved, the anodic and cathodic areas were electrically isolated. The current was then allowed to flow through a sensitive galvanometer. Such anodes were prepared by polishing specimens from both center and edge of billet; the specimens were then coated with a thin layer of nonconductive plastic. These coatings were pierced at the inclusion site by a Vicker microhardness tester. Enough openings were made by the diamond indenter to expose the entire inclusion surface. One typical exposed inclusion

Inclusion Areas and Corrosion Currents

Electrolyte	Total Anodic Area Exposed	Total Current	Anode Current Density
Dilute NaCl (0.001 *N*)	0.000750 sq.mm.	11 micro-amp.	1.47 amp. per sq.cm.
Dilute NaCl (0.001 *N*)	0.000157	11	7.00
Dilute H_2SO_4 (2%)	0.000750	7	0.93
Dilute H_2SO_4 (2%)	0.000157	8	5.3

is illustrated in Fig. 3, with the nonconductive plastic film appearing as wavy lines. As the diagram (Fig. 4) illustrates, the "cell" was constructed from a plastic-coated specimen with an exposed inclusion (anode), a polished billet specimen (cathode)*, and an electrolyte. A sensitive galvanometer was connected between the anode and the cathode, and the electrodes dipped in the electrolyte. The data obtained are presented in the table.

From this table it is apparent that the large inclusions have a surface area about five or six times that of the small ones. However, for both large and small inclusions, the total current was about the same. Therefore, the current density at the small inclusion is about five or six times greater than in the larger inclusions. Since attack at small inclusions is much more intense, it can be easily seen that there may be occasions when only small inclusions will show up in sulphur printing.

For example, the toolsteel investigated contains sulphide stabilizers which may retard attack by dilute acids. In other steels, where all the sulphides are more readily attacked, even the large sulphides may affect the photographic paper. Where the sulphides are more corrosion resistant, as in this instance, the slower attack does not affect the paper, and misleading indications result. Consequently, sulphide printing may not be suitable for all types of materials.

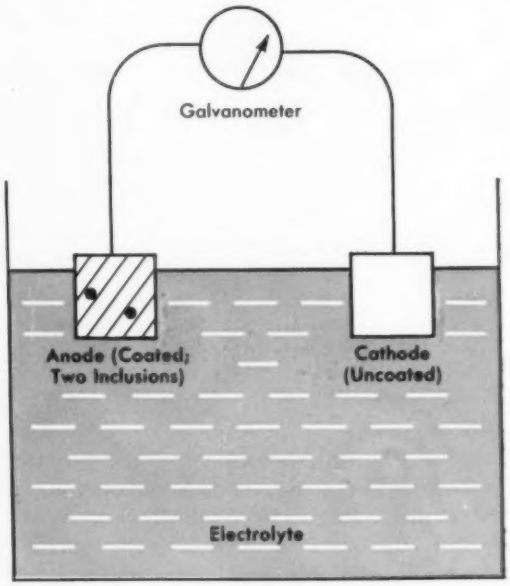
*While this specimen also contains inclusions, it must be remembered that the entire surface of the cathode is exposed. The average electrical characteristics are still essentially those of the metal alone, since the inclusions are very small in relation to the metal area.

Fig. 3 – Plastic-Coated "Cell" Test Specimen With Exposed Inclusion. The opening through the film was made with a Vickers microhardness tester. Wavy lines are caused by light refraction between coat and specimen surface

Conclusion

A sulphur print is an excellent method for delineating sulphur dispersal in steel, but can be erroneous in some instances. Results must always be carefully evaluated with reference to information other tests reveal.

Fig. 4 – Diagram of Cell for Corrosion Current Measurement. Current densities indicated that small inclusions erode more rapidly than large inclusions



The Windscale Atomic Piles

By TOM BISHOP*

Ten years ago the British Government built two plutonium-producing piles at Windscale, similar to the American piles at Hanford except the coolant was atmospheric air rather than river water. Both of these piles were shut down about a year ago because the graphite moderator was dangerously overheated by "Wigner energy". It is unlikely that the British power-producing piles which use carbon dioxide as coolant and heat-transfer medium will be similarly endangered. (W11p)

THE DISCOVERY last October of red-hot uranium cartridges in Pile No. 1 (one of the two plutonium-producing piles at Windscale) led to a full-scale technical investigation. As shown in the sketch, Fig. 1, natural uranium is used as the fissionable material and the canned slugs are placed in parallel horizontal channels in a block of pure graphite as the moderator. Atmospheric air is used for cooling; after passing through the channels in the graphite block, it is filtered and vented through a tall chimney. The incident was briefly described in *Metal Progress* for January 1958, and a little further data added in the correspondence columns in the June issue. The final report of the technical evaluation committee has now been published; it is referred to as the Fleck Report after the committee's chairman, Sir Alexander Fleck.

The British Atomic Energy Authority decided that it would not be economic to rebuild the Windscale Pile No. 1 in which the trouble arose, and also that Pile No. 2 should not be restarted, since it would cost at least $1,500,000 to make the necessary modifications in it for safety, and this is noneconomic for a device that was designed for an active life of ten years, and has survived seven of them.

Wigner Energy and Dislocations

Wigner stored energy is the extra energy belonging to those crystalline defects which are produced by neutron bombardment. Such bombardment knocks atoms out of their normal positions. These displaced atoms can move about inside the material and gradually find their way back to normal positions or other configurations; the stored energy at these new sites is then totally or partially released in heat. It is useful to regard such a defect or dislocation as having a certain life, which is the time required for it to release its energy by the process just described. Two important aspects must be considered:

First, because of differences in distribution of the defects within the graphite and because of the differences in the various types of such defects, the life may vary over a very large range of time at any particular temperature. For in-

*John Miles & Partners (London) Ltd., England.

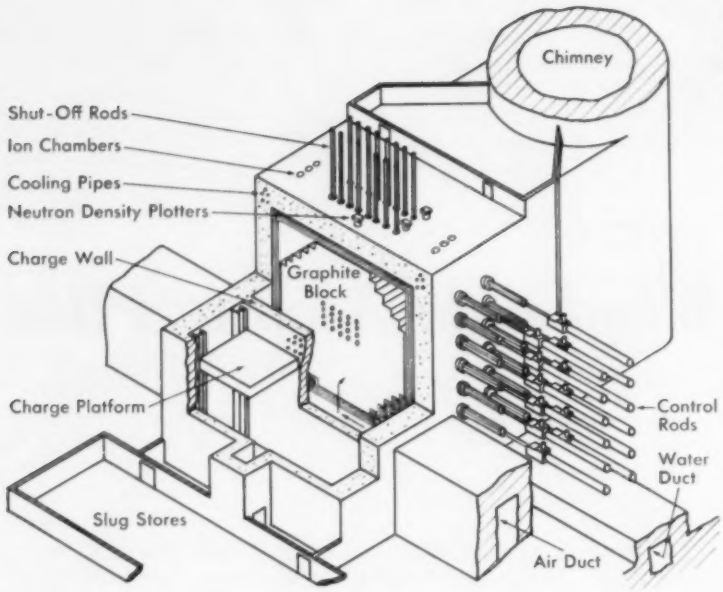


Fig. 1 – Perspective Cut-Away Showing Construction of Great Britain's Plutonium-Producing Piles at Windscale

stance, at room temperature it may vary from a fraction of a second to some hundreds of years. It follows that some defects in the graphite moderator will disappear and release their energy very quickly, while others will last for an almost indefinite time.

The second important feature is that the lives all become shorter as the temperature of the graphite is raised. For those which live a few hours at 100° C., the lifetime is reduced by a factor of approximately 2.5 for each 10° rise in temperature in the range between 30 and 100° C. Thus a defect with a life of one year at 30° C. can be released in about one day at 100° C. The number of such defects that can be accumulated during one year's irradiation in the graphite of a reactor such as the Windscale pile is very large, and the energy that would be released by them in one day, at 100° C., is correspondingly large.

When a defect releases its energy, this energy (unless removed by a coolant) will warm the surrounding graphite and so help neighboring defects to release their energy more quickly. If there is no cooling, therefore, and if there is a sufficient number of defects present, the Wigner release develops at an increasing rate until the stored energy belonging to these defects is released.

The above general phenomena have been known for some years, but when the Windscale piles were designed and built, knowledge about the conditions under which Wigner energy could be released was not very clear. An accidental release of Wigner energy occurred in Pile No. 1 in September 1952, while the pile was shut down and the main cooling fans were off, and periodic deliberate releases of Wigner energy have been carried out since then.

The main features of this storage of energy may be summarized as follows:

1. Total stored energy accumulates with irradiation dosage, and since temperature has a large influence on the life of the defects, the rate at which energy accumulates decreases considerably as the temperature during irradiation is increased. It is known that virtually no energy is stored from irradiations at temperatures above 400° C., and even the amount stored above 250° C. is small.

2. The energy stored in graphite in reactors operating at low temperatures can be classified loosely into a low-temperature component and a high-temperature component, according to the temperatures at which the energy is readily released.

3. The low-temperature component can be released by raising the temperature into the range 100 to 200° C. If the release of this component takes place, the heat (in the absence of cooling) will raise the temperature of the graphite. It may reach 300 to 450° C., depending on the amount of energy stored. There is experimental evidence that the energy content of this component does not increase indefinitely with prolonged irradiation.

4. The release of the high-temperature com-

ponent begins at about 300° C., but is not completed until the graphite is heated to temperatures exceeding 1000° C. (1825° F.) for it takes place gradually over a wide range of increasing temperatures. Only a small part of it can be released at any particular temperature within this range. For the amounts of irradiation received by graphite in the Windscale reactors, the part of the stored energy associated with this component that is releasable in the range 300 to 500° C. is not enough to carry the temperature of the bulk of the graphite much beyond that reached by the release of the low-temperature component.

On the basis of the information now available from Windscale Pile No. 2, the Fleck committee concluded that, if a further energy release on this pile were carried out by previous routines, temperatures higher than 400° C. would almost certainly occur in considerable masses of graphite. Moreover, it is likely that pockets of graphite would exist from which the stored energy was not released on some previous occasion and, in the absence of cooling air, could reach temperatures as high as 500° C. To verify this assumption, it would be necessary to take a very large number of graphite samples from the pile.*

Effect on Various Components

Since, as stated above, the release of the low-temperature component of the stored energy could lead to local temperatures even up to 500° C., it is important to examine the effects of such temperatures on the various materials which are in the pile.

Graphite – At sufficiently high temperatures, graphite oxidizes rapidly in the presence of air, with the production of considerable heat. The rate of oxidation, and consequently the rate of heat production, increases rapidly as the temperature rises. Thus the graphite in a pile must never reach a temperature at which the rate of heat production by oxidation is greater than the rate at which it can be removed. It has also been found that graphite which has been subjected to prolonged irradiation, as in the Windscale piles, oxidizes more readily than unirradiated graphite, and that quite small quantities of various contaminants deposited from the cooling air greatly enhance the oxidation rate.

The temperature to which the graphite in a pile can safely be permitted to rise depends upon the oxidation rate and the amount of cooling available. Present information from Pile No. 2 (the surviving pile) indicates that the air from the main blowers of Pile No. 2 would remove the heat produced by oxidation of the graphite at temperatures up to about 550° C. If reliance had to be placed on the shutdown fans connected to a guaranteed (emergency) electrical supply, the permissible maximum temperature would be about 450° C. However, there may be regions where the effect of contamination mentioned above is very large and where the permissible maximum temperature might even be somewhat less – perhaps 400° C. These considerations do not apply to the British power reactors at Calder Hall, which are cooled by carbon dioxide instead of air, since no heat is liberated when graphite and carbon dioxide react; on the contrary, heat has to be supplied to sustain such a reaction.

Uranium Fuel – The fuel cartridges in the Windscale piles consist of natural uranium bars in aluminum cans. If the can fails, some uranium will be exposed to the air and may oxidize. Even a small pinhole in a can may be sufficient, and the uranium oxide would eventually damage the can sufficient to expose a substantial area of uranium. Oxidation would then proceed more rapidly, generating heat locally; furthermore, the fission products in the bare uranium would escape into the coolant and be drawn up the chimney.

Thus, the first objective is to prevent any failure in any can. Much effort has been devoted to this (in England as well as in America). Although occasional and usually minor failures occur during normal operation, the present design of fuel element is considered satisfactory.

Since it is impossible to guarantee that uranium fuel cartridges which are being irradiated and cooled by air will remain completely and continuously sound, safety in reactor operation, both under normal running and during any planned Wigner release, will depend on two things:

1. The ability to detect, and then discharge, a faulty cartridge at an early stage. Adequate apparatus for the detection of failures must therefore be available at all times.

2. Maintenance of an operating temperature

*Editor's Footnote: Freedom from such trouble in the piles at Hanford may be due to two prime differences in circumstances: (*a*) Cooling by a generous flow of water should always keep the average temperature of the graphite block considerably lower than in the air cooled reactors at Windscale; (*b*) The air coolant at Windscale continuously brings oxygen to feed any incipient combustion at an exposed hot spot.

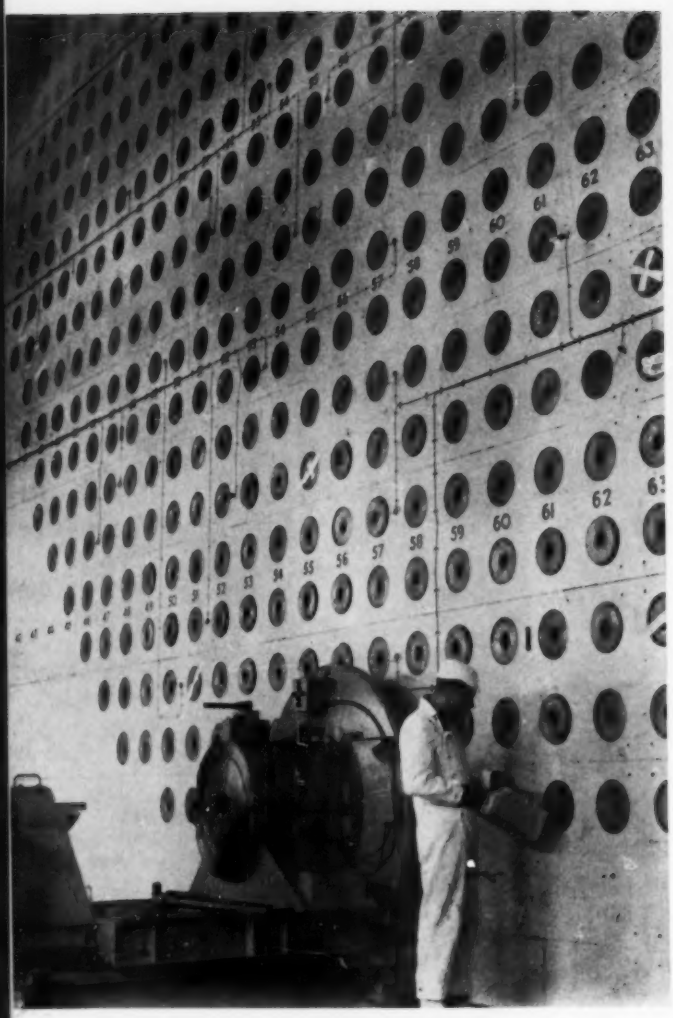


Fig. 2 – Charging Machine. Operator is monitoring a loading port. Both stand upon an elevator platform adjustable to any row of fuel channels. The equipment is behind a concrete barrier and the enclosed space is slightly pressurized and is entered through an air lock

low enough to avoid rapid oxidation of uranium should a fuel cartridge fail.

Other Materials – Because of the limits to the temperatures which the reactor can be allowed to reach, certain operating restrictions are also necessary for all the other constructional materials. In particular, it is desirable that they should be capable of standing temperatures in excess of the permissible limits for the graphite and uranium. Given this, they could never be the cause of a fire nor would they require instruments to record their temperature, nor the imposition of any additional restriction on the operations.

On this basis, none of the structural materials in the Windscale reactors would cause any trouble. The principle is important, however, in relation to any materials inserted in the reactor for the production of isotopes or for irradiation testing or other experimental purposes.

Instrumentation

It is necessary to know (*a*) the temperature and rate of change of temperature in both the fuel and the graphite, (*b*) the neutron flux and its rate of change, and (*c*) the amount of fission product in the coolant. This will require more measuring instruments and recorders, placed in the correct position. If a planned release of Wigner energy is undertaken, additional information about temperatures in the reactor will be needed.

The Fleck report recommends that about 100 thermocouples should measure fuel temperatures and a further 200 would be needed during a Wigner release. Another 300 should be installed to record graphite temperatures. It is essential that the indications be displayed in a form which is immediately available to the reactor operator, but such data-processing and display systems have been developed for normal industrial use.

Planned Energy Releases – A combination of methods for releasing Wigner energy from an air cooled reactor would appear to be a satisfactory technique. The graphite temperature would first be raised slowly to 120° C. by heating the ingoing air, and would be maintained there for about 12 hr. The pile would then be cooled down to room temperature. (This preliminary heating would remove some of the Wigner energy and reduce by about 80° C. the maximum graphite temperature that might be reached in a subsequent self-sustaining release. The maximum graphite temperature would then be within acceptable limits.) Next, the graphite temperature would be raised rapidly to about 160° C. by heating the ingoing air. This would bring about the release of the remaining low-temperature stored energy.

This method would be effective, since all the graphite could be heated by hot air, and it would not be necessary to rely on transfer of heat from block to block. The resulting stresses in the concrete structure would also be less severe.

As in the American plutonium-producing piles, it would be possible to specify conditions whereby the pile could be operated without further

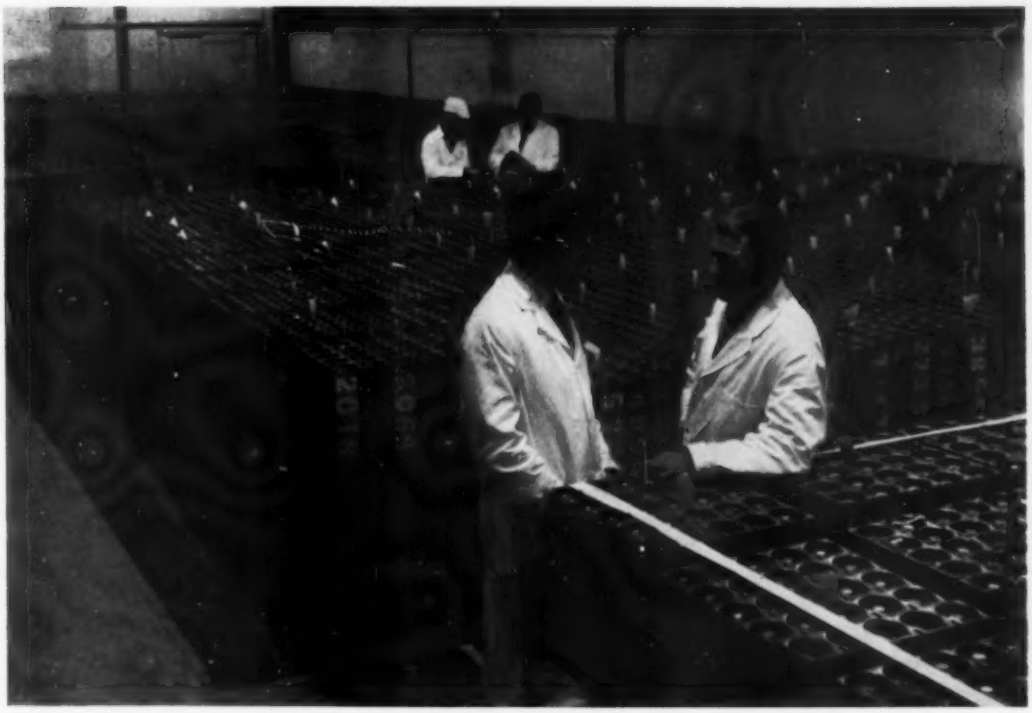


Fig. 3 – Unused Fuel Elements in Storage in Air-Cleaned Room

release – this by controlling strictly the graphite's temperature. Nowhere would it be allowed to rise more than 20° C. above its operating temperature except at a rate of less than 1° per hr. This condition can be readily met as far as the bulk or average temperature is concerned, but it is more difficult to avoid any local hot spots. It would be impossible to install a sufficient number of thermocouples to check this situation. Special precautions in the operational procedure must insure that an unwanted rise of graphite temperature could not be caused through the movement of fuel elements, isotope cartridges or variations in coolant. While it would be possible to operate an air cooled pile safely in this manner, there would inevitably be a loss of flexibility in the loading, and an added responsibility would be imposed on the operating staff at all times. As a further precaution an adequate guaranteed supply of cooling air would have to be available at all times to insure that the graphite temperature would always fall at shutdown.

Operation of Calder Hall

The above considerations have also been carefully examined as to their relations to operation of the neighboring power-producing piles of Calder Hall.

There are several important differences between the Windscale and Calder Hall reactors. In the first place, all the graphite temperatures in Calder Hall operations are much higher than in the old ones at Windscale and releases of Wigner energy are therefore required less frequently despite the higher intensity of radiation. Samples taken from the Calder Hall system show that the present condition of the graphite is perfectly safe; the energy stored after two years' operation is too small to produce a self-sustaining Wigner release and is likely to remain so for at least two more years. A moderate increase in the graphite temperature to increase the power output would make it unnecessary for any Wigner release to be undertaken during the whole working life of these reactors.

A second difference is that the power reactors are cooled with carbon dioxide, and the problems associated with the oxidation of uranium and graphite by the coolant do not arise. From the point of view of the emission of fission products from faulty cans, a further essential difference is that the coolant in Calder Hall reactors circulates in closed circuit.

Book Review

A Comprehensive Appraisal of Molybdenum

*Reviewed by J. GORDON PARR**

THE METAL MOLYBDENUM, edited by Julius J. Harwood, American Society for Metals, Cleveland, 1958, 696 p. $12.50

ONE OF THE OCCUPATIONAL HAZARDS that faced the Homeric male was the possibility of being transformed into a beast by that attractive dish, young Miss Circe. Odysseus, having lost a number of his best friends this way, would return them to human form by treating them with the magical herb, *moly*. Which I mention only to show that the word *molybdenum* has always had an extraordinary root, in more senses than one; and the character of the metal seems to be in keeping with the legend.

I am sure of molybdenum's potentialities, now. But before I read "The Metal Molybdenum" my knowledge of the metal was limited to facts that we all know: Molybdenum's remarkable creep resistant properties at high temperatures are only marred by a tendency to rapid oxidation. How many of us, I wonder, have spun this single wisp of knowledge into a 1-hr. lecture web?

"The Metal Molybdenum" is more than a factual account of the metal and its major alloys; it communicates an infectious enthusiasm, and I suspect that many of its readers will become "molybdenomanes".

The vitality of the book is conveyed through all its two dozen or more contributors. Naturally, the standard of the writing, and the shrewdness of the views expressed, vary but in all parts the book is fascinating reading.

The book is conveniently divided into five sections: Two short introductory chapters describing molybdenum, the structural metal (20 p.), followed by a substantial description of the preparation and fabrication (170 p.), a section relating to the physical metallurgy of molybdenum and its alloys (180 p.), gas turbine applications (100 p.), and a short account of European developments (30 p.). The appendices, including binary constitutional diagrams and a selected bibliography, should not be overlooked.

Each chapter made its arresting observations. For instance, I had even forgotten (or perhaps I never knew) the implications of the simple physical properties of molybdenum: its very high thermal conductivity and low specific heat allow it to be rapidly heated and cooled with low resultant thermal stresses.

There are many aspects of the book which, while directed to the metallurgy of molybdenum, are apposite to other metals, particularly to reactive and refractory metals. The techniques of consolidation by powder metallurgy practice (remember the easy contamination of the metal) and of subsequent arc melting are capably described. These subjects, and the concise analysis of the relative merits of sintered and melted molybdenum products, have broad implications. Even the discussion of oxidation protection by coatings, while limited to molybdenum, has wider implications, since corrosion protection of most metals has only been patchily investigated. The solution to forging problems – molybdenum is cold worked at temperatures as high as 2400° F. – is reassuring to those of us who may have lesser forging problems.

In the section devoted to physical metallurgy, an effort is made to relate the similar behaviors of a number of metals. The physical metallurgy of molybdenum is thoroughly and clearly revealed in chapters on single-crystal behavior under stress, on the ductile-brittle transition and on the effects of contaminants on ductility.

So, while the title of the book clearly enough expresses an intention to deal specifically with molybdenum, most metallurgists with inquiry in their minds, hope in their hearts and a few dollars in their pockets, should buy a copy.

*Professor of Metallurgy, University of Alberta, Edmonton, Alberta.

Short Runs

Vacuum Furnace for Continuous Strip

THE PHOTO AND SKETCH in Fig. 1 show a vacuum furnace for heat treating strip or wire continuously, which has been operating in the experimental department of the Electric Furnace Co., Salem, Ohio, for the past two years. The electrically heated pilot furnace operates up to 2100° F. and can handle strip up to 4 in. wide by 0.030 in. thick. Metals investigated include tantalum, titanium, zirconium, high-carbon steels, and stainless steels of the 200, 300 and 400 series and precipitation hardening type. Entrance to and from the vacuum system is through a mercury seal.

A furnace of this type may be heated electrically or fuel fired. If equipment is heated electrically, engineers at Electric Furnace Co. say there is no practical limitation on strip width because the heat treating operation can be conducted in a refractory-lined chamber and the portion of the equipment which must resist atmospheric pressure will remain at room temperature. However, if the furnace is fuel fired, the strip width would be limited by the size of the alloy muffle tube available.

Strip Must Be Clean

The vacuum strip furnace has been operated with pressures maintained at less than 1 micron. However, the strip must be clean before entering the furnace if low internal pressures are to be held. Other factors which influence the vacuum level are the amount of outgassing of strip and the size and number of vacuum pumps.

For production-size units, a vertical furnace may offer advantages over the horizontal type now used in experimental work. However, EF's engineers can see no reason why either type would not be successful. A typical design for a vertical furnace for bright annealing 1000 lb. per

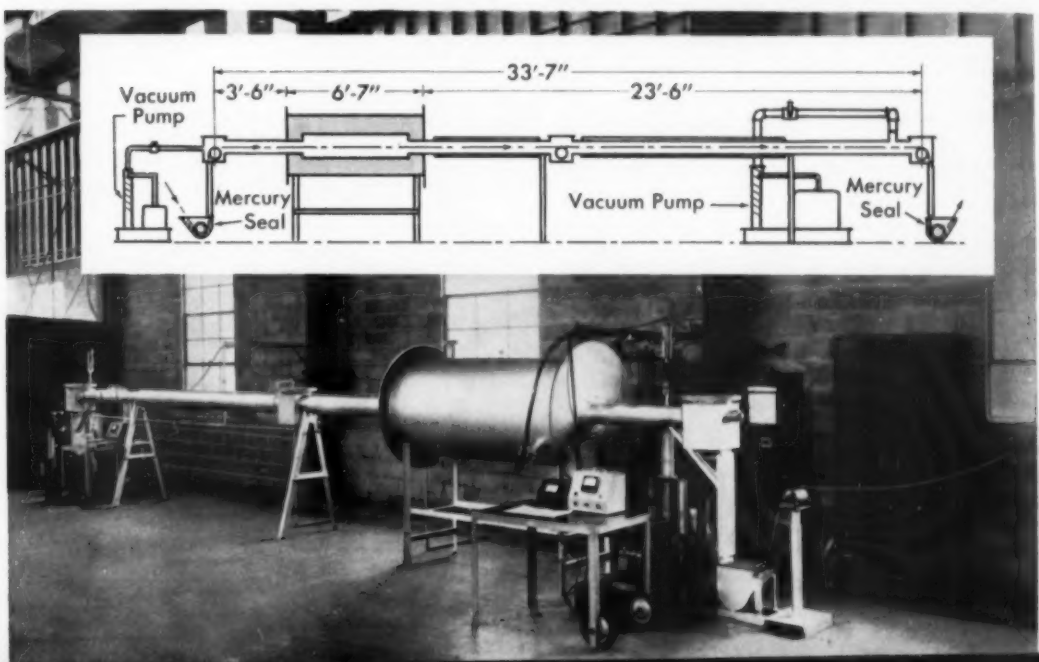


Fig. 1 — This Pilot Model Vacuum Strip Furnace Is Operating in the Electric Furnace Co.'s New Development and Research Building

hr. of stainless steel strip is shown in Fig. 2. A design of this type has also been proposed which will handle 2000 lb per hr.

How does the cost of vacuum annealing compare with conventional bright annealing?

To answer this question, Ralph J. Perrine, director of research at Electric Furnace Co., provided *Metal Progress* with the estimated costs shown in the table. They show a slight advantage in favor of conventional annealing equipment, so far as first cost is concerned. However, this appears to be more than offset by the savings in operating cost. The comparison of operating costs does not include such items as insurance rates, life of the alloy retort in the gas-fired furnace or maintenance of the vacuum pumping equipment. Even so, Mr. Perrine feels that a comparison including these minor items would still show that conventional bright annealing equipment is about twice as expensive to operate as continuous vacuum equipment.

In addition to being cheaper to operate, other advantages of the vacuum process are:

• Heat treating in vacuum is 100% neutral to all surface compositions. It is impossible to bright anneal some grades of stainless in dissociated ammonia without acquiring a thin nitrided case. In rolling the heavier gages, this slight change in surface composition is perhaps not too important. But in the thinner gages—0.005 in. and below—a case depth which is barely perceptible is detrimental to the physical properties of the material.

• An appreciable amount of degassing occurs during vacuum annealing to give improved physical properties. The extent depends upon the vacuum and temperature in the annealing chamber and the time of treatment. The effect of outgassing may be rather small on the heavier

Estimated Cost of Bright Annealing in Atmosphere Compared With Vacuum*

Equipment	Gas-Fired Muffle Type	Electrically Heated Strip Vacuum
Furnace	$140,545†	157,685‡
Field installation work	14,000	14,000
Proportioning type control	—	7,800
20,000 lb. anhydrous ammonia storage	6,100	—
Total	$160,645	179,485
Operating Cost		
Power (1.08¢ per kw-hr.)	355	8,345
Water (0.60¢ per 1000 cu.ft.)	575	850
Natural gas (0.66¢ per 1000 cu.ft.)	6,560	—
Anhydrous ammonia (0.05¢ per lb.)	14,850	—
Total	$22,340	9,195

*Cost per year on basis of 1000 lb. per hr. of stainless strip.

†Includes cooling hood, vacuum pumps, degreaser and terminal equipment.

‡Includes equipment for dissociated ammonia atmosphere, degreaser and terminal equipment.

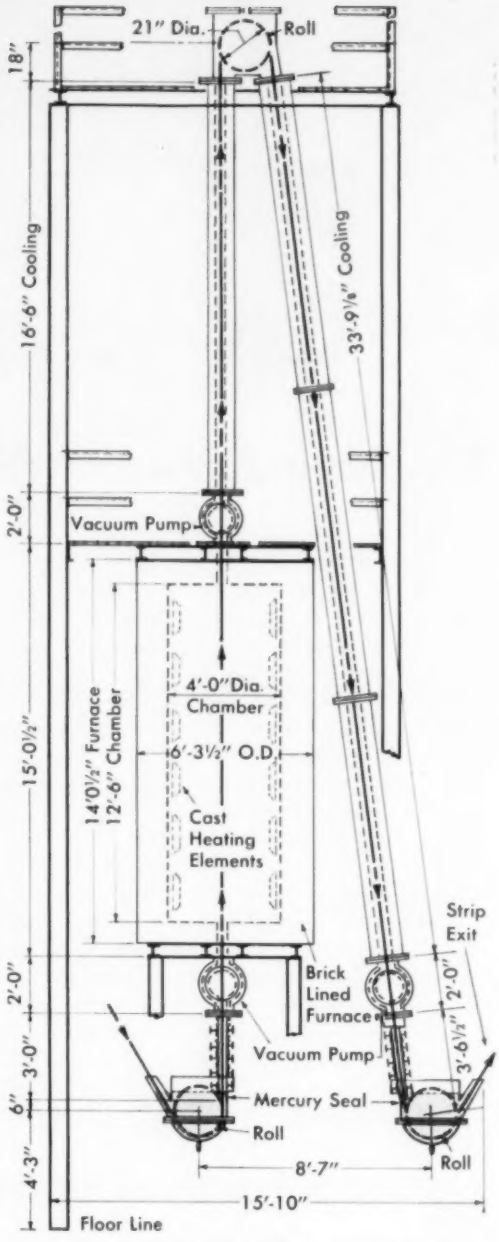


Fig. 2—A Vertical Continuous Vacuum Furnace of the Type Now Being Considered by a Number of Major Steel Producers for Bright Annealing Stainless Steel. Capacities range from 200 to 2000 lb. per hr.

stock. However, it may be quite important in the thinner gages of high-priced specialty metals.

• Vacuum heat treating completely eliminates the explosion hazard and the need for protective devices with atmosphere generator equipment.

Improved Chromium Plate

THICKER CHROMIUM, plated as a "duplex" deposit, promises to give automotive bumpers and other trim parts a bright finish with much better corrosion resistance than they have had in the past. The new plating method developed by Metal & Thermit Corp. consists of an initial application of a bright crack-free chromium plate (bath CF-520) for optimum coverage and build-up in low current density areas. This is followed by a second bright deposit of finely cracked chromium (bath CR-110). The duplex chromium plate, with total thickness of 0.10 to 0.20 mil, is applied over suitable undercoats of copper-bright nickel on zinc die-cast or steel parts.

The corrosion of bright-plated automotive parts which has caused so much concern is due to rapid pinhole rusting and blistering attributed to electrolytic cell action. This corrosion is a "stripping" action where the rate of penetration and removal of metal depends upon the cell potential. The higher the cell potential (voltage) the more rapid is the rate of stripping – which means faster corrosion. Since electroplated metals normally do not bridge defects, a few isolated spots corrode rapidly because all the cell potential is concentrated at those defective spots.

When a finely cracked chromium is deposited on top of the crack-free chromium, the rate of corrosion is markedly reduced. Edgar J. Seyb, Jr., research supervisor of Metal & Thermit's electrochemical research laboratory in Detroit, explains that this is because the many cracks over the entire surface disperse cell action over a large area. Therefore, there is a substantial reduction of the current density at each of these many individual openings. This keeps the current density below the value corresponding to the critical potential needed for anodic perforation of the underlying metals.

While a single thick layer of crack-free chromium gives significantly better corrosion protection, a second deposit of finely cracked chromium improves corrosion resistance a great deal more – extending the CASS* test performance with 0.10 mil of chromium to about 200 hr. (ordinary chromium shows appreciable corrosion in 48 hr. as shown in Fig. 1). Corrodkote tests, normally stopped after one 16-hr. cycle (roughly equivalent to one year of outside exposure), had to be run six complete 16-hr. cycles to reach the same degree of failure.

Although it is more difficult to protect zinc-base die castings than steel, Dr. Seyb stated that the new duplex chromium process is producing

*An extension of the more familiar acetic acid salt spray test, the CASS test adds copper chloride to the test salt solution and also increases test temperature. The rate of attack is speeded up from four to six times. The Corrodkote test follows procedures developed by Chrysler Corp.'s engineering department, in cooperation with the American Electroplaters' Society's Research Project No. 15. In this test, which is used by both Ford and Chrysler, a standard corrosive slurry is applied as a uniform coating on the part. After the coating dries, the test piece is placed in a noncondensing humidity cabinet for 16 hr., then cleaned and inspected. The slurry is applied at the beginning of each additional cycle. Exposure to 16-hr. of either Corrodkote or CASS test is generally accepted to be equivalent to one year's service in the Detroit area.

Fig. 1 – These Steel Bumper Parts Were Given an Under Coat of 0.4 Mil Copper Followed by 0.8 Mil Nickel. The part on left received 0.01 mil of ordinary chromium plate and was given a 48-hr. CASS test. Part on right, which shows much less corrosion, was plated with 0.20 mil of duplex chromium and tested for 325 hr. in CASS test. Exposure of 16 hr. in CASS test is generally accepted as equivalent to one year's service in a city such as Detroit

improvements of 100% or more in corrosion resistance on regular production run die castings. One commercial plater who was using 0.01 mil of chromium over normal undercoats on die castings had only 10% of his parts pass a 16-hr. CASS test. Now, with duplex chromium, over 80% of the parts pass a 32-hr. CASS test.

Production Methods

In chromium plating installations now producing duplex coatings, the procedure is to plate a minimum of 4 min. in the crack-free bath (CF-520) at an average current density of 1 to 1½ amp. per sq.in. at 8 v., with a bath temperature of 120° F. This is followed by a reclaim rinse and a water rinse. Parts are then plated under the same conditions for another 5 min. in the solution (SRHS special CR-110) which produces a finely cracked deposit. This method deposits about 0.1 mil total chromium in the average current density areas; minimum plate thickness in low current density areas is much greater than with ordinary chromium plating.

If the equipment in use does not provide enough length for a second chromium solution, a separate tank can be used to plate the second layer of the duplex coating. If the work dries between these operations, parts should be cleaned by soaking for 3 to 5 min. at 180° F., without current, in an alkaline electrocleaner. This is followed by two cold running water rinses and then chromium plating.

Brazing by Exothermic Reaction

A NEW PROCESS for joining metal structures utilizes a controlled exothermic reaction. Honeycomb panels of stainless steel have been made this way, in which the exothermic material is sprayed over the skins of the panel, then ignited. After the braze alloy has melted and flowed, the panel is die quenched. The entire brazing operation takes only 2 to 5 min. and cost is less than $1.50 per sq.ft.

According to Roger A. Long, Narmco Industries, Inc., San Diego, Calif., the process is unique in that temperatures can be closely controlled and a large variation in section thickness can be tolerated. Panel size is limited only by the size of holding fixtures, and the process can be adapted to fabrication of continuous flat panels. Variations of the process can be used to repair welded and brazed structures in the field. In the future, this technique may be applied in space-brazing of metal structures; this can be done with a material applicator and a 3 to 6 v. ignition dry cell battery. The exothermic principle has other possible applications in heating refractory alloy sheet for forming and in preheating prior to explosive forming.

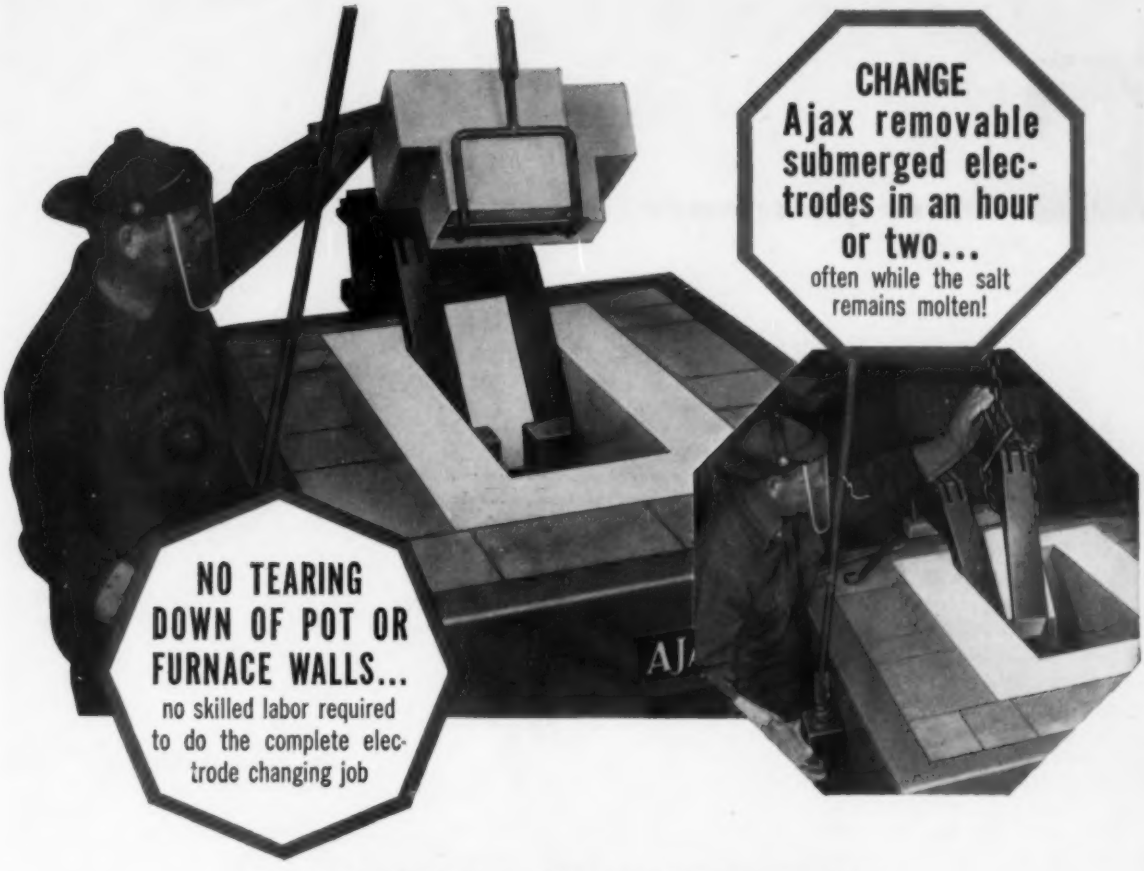
Bonded Carbides for Corrosion Resistance

SHOWN FOR THE FIRST TIME at the Design Engineering Show in Philadelphia were two new sintered carbide compositions developed by Kennametal Inc., Latrobe, Pa., for corrosion and wear resistant applications. One is a binderless carbide of tantalum and tungsten (called K 601) proposed for uses where the maximum corrosion resistance of the more expensive platinum-bonded tungsten carbide is not required. The material is being tested for seal rings in valves, orifice parts, ball and seat valves and compacting dies. Its nonmagnetic properties are useful for wear parts in magnetic wire and tape.

The other composition is tungsten carbide with a chromium-cobalt binder (called K 701) which has excellent wear resistance for less severe corrosive applications. Its cost is less than that of the binderless carbide above and it is more corrosion resistant than conventional carbides. It is being tested in nozzles, catalyst compacting dies, valve balls and seats, and for wear parts of coal processing machinery.

High-Temperature Crucible

ALSO SHOWN at the Design Engineering Show were crucibles made of dense, nonporous, 99.8% pure magnesia which can be used up to 4350° F. for melting high-temperature alloys and basic slags. Corning Glass Works, Corning, N. Y., reports that the new magnesia ceramic can be slip-cast, pressed or extruded into a variety of shapes. Melting point of the magnesia is over 5000° F., and it possesses the thermal characteristics of an ablating material. The mechanical properties of the ceramic are said to be good: Modulus of rupture at room temperature is about 15,500 psi. and hardness is 585 on Knoop 500 g. scale. Data are also available on thermal conductivity and thermal expansion.


CHANGE
Ajax removable submerged electrodes in an hour or two...
often while the salt remains molten!
NO TEARING DOWN OF POT OR FURNACE WALLS...
no skilled labor required to do the complete electrode changing job

This Ajax development
CUTS SALT BATH MAINTENANCE TO NEXT TO NOTHING...

AJAX
HULTGREN

SALT BATH FURNACES
Internally heated electric and gas-fired types

Largest line of types, shapes and sizes, manual or mechanized, for modern production requirements.

Avoids production tie-ups, too!

Now you get all the advantages of closely spaced, vertical submerged electrodes in your salt bath furnace — with almost none of the previous high cost or time loss in putting in new ones. Simply lift a removable block on top of the furnace and the electrodes are fully accessible for a fast, easy change by unskilled labor.

Now widely used on new Ajax electric salt bath furnaces, this feature can often be added to old ones at moderate cost. And here's still another heat treating maintenance tip: Send worn electrodes to Ajax for "restubbing." They come back to you good as new — at a substantial saving over the price of new ones!

Write for Removable Submerged Electrode Bulletin 810.

AJAX ELECTRIC COMPANY
910 Frankford Avenue Philadelphia 23, Pa.

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Correspondence

Crack Sensitivity of Aluminum Alloys

REDSTONE ARSENAL, ALA.

Crack sensitivity of the high-aluminum alloys in the Al-Cu-Mg-Si system has been widely studied, and we felt it would be useful to coordinate the test results in the form of a regular tetragon (equilateral pyramid). Crack sensitivity is ordinarily measured as inches of surface cracking in an inch-thick ring of the alloy cast around a steel pin.

Information obtained from "Research Into the Welding of Aluminum", published by the Aluminium Development Assoc. of England, that was checked against a report of the Aluminum Co. of America and is now being spot checked by Kaiser Aluminum Co., was useful in preparing the needed diagrams. Linear inches of cracking of ternary alloys were plotted at the positions on the faces of the plastic pyramid corresponding to their analyses. Quaternary alloys were spotted on shelves at the right elevation. Logarithmic coordinates gave an expanded scale at the high-aluminum end. Contour lines showing linear inches of cracking are reproduced in Fig. 1 to 4 herewith.

We have used this diagram to indicate analyses where excessive cracking can be anticipated, and also to guide mixtures of alloys. Undesirable cracking of five linear inches may not be avoidable but should be diluted with nonsensitive filler metal when welding. Again, welding wire alloy for joining two like or unlike alloys may be selected by avoiding crack sensitive alloy areas. The 1% Si alloys exhibit the

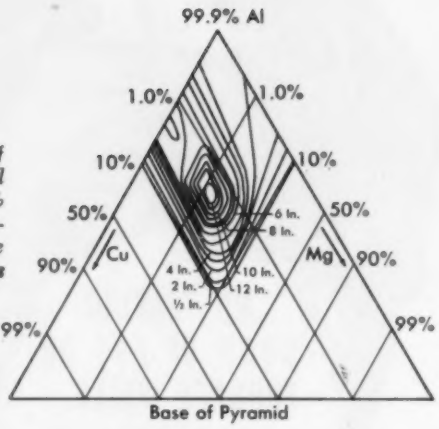


Fig. 1 (Right) – Al-Mg-Cu Face of Mg-Cu-Al-Si Pyramid. Ternary Al alloys containing more than 10% each of Cu and Mg are crack resistant. Note that all figures are plotted with logarithmic coordinates

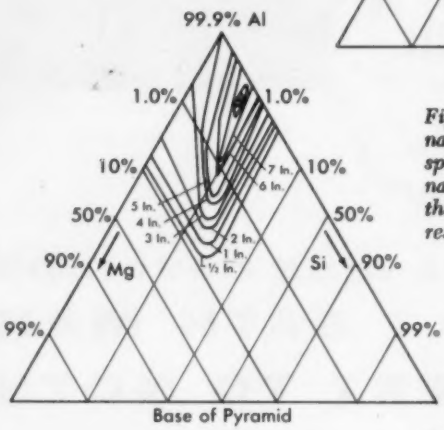


Fig. 2 – Al-Mg-Si Face of Quaternary Pyramid. Left edge corresponds to right edge of Fig. 1. Ternary Al-Mg-Si alloys containing more than 10% Mg and 3% Si are crack resistant (5 in. may be tolerated)

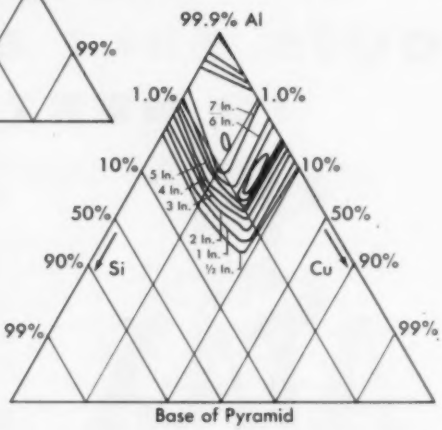


Fig. 3 – Al-Si-Cu Face of Pyramid

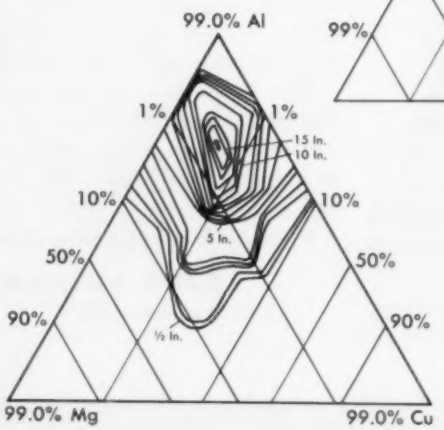
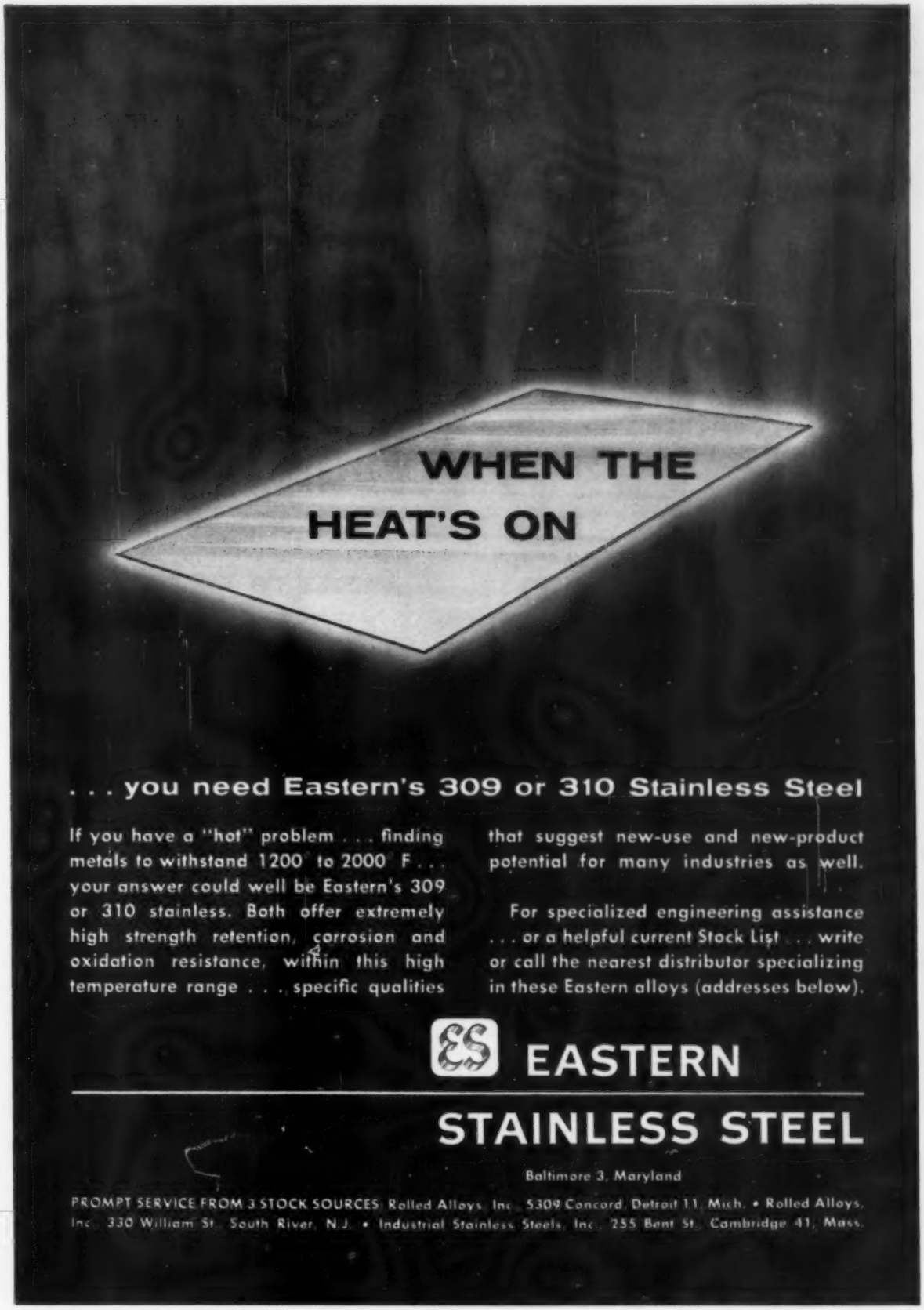


Fig. 4 – 1% Silicon Shelf of Ternary Model



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worst conditions (15 in.) and should definitely be avoided.

The above represents the combined work of the undersigned, a government engineer, Paul Schuerer of Chrysler Missile Operation (a prime contractor) and Don Davis of Hayes Aircraft Ordnance Operation (a sub-contractor).

JAMES K. DAWSON
Welding Engineer
Army Ballistic Missile Agency

EDITOR'S NOTE – Mr. Davis is responsible for the handsome background of colored spherical triangles for one of these tri-axial diagrams which appears on the front cover of this magazine. It was exhibited at the last National Metal Exposition, along with a dozen other pieces of cover art, and in the popular vote registered well up toward the top.

Ship Plate Steel

WASHINGTON, D.C.

In "Mill Sampling of Ship Plate Steel", a digest of the Ship Structure Committee Report SSC-106 "Mill Sampling Techniques for Quality Determination of Ship Plate Steel", published in the February 1959 issue of *Metal Progress*, p. 152, the reviewer states that "little variation was found in the properties of plates from edge to center although considerable segregation occurred." The data in the report show that while there is no consistent trend from edge to center when all plates are considered, individual plates do exhibit large variations in notch toughness across the plate width.

An erroneous impression of the transition temperature values reported for the two grades of steel is also presented. For example, only one plate of Class B steel had a 15-ft-lb. transition temperature as high as 40° F. (which the reviewer gives as representative of this grade), while the values given for Class C steel are for the plate showing the best notch toughness. The average value of the 15-ft-lb. transition temperature for Class B was 30° F., for Class C −19° F.

CHARLES L. STAUGAITIS
Metallurgist
National Bureau of Standards

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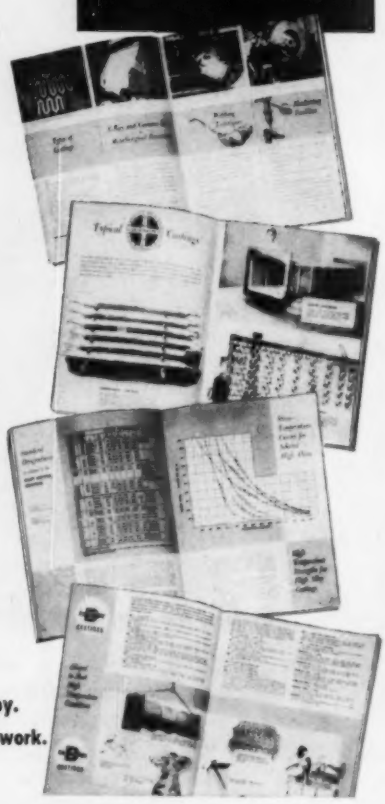

This is our New General Bulletin—3354G. It's full of information and data on the chrome-iron and chrome-nickel castings so necessary when corrosion, high temperatures and abrasion must be resisted. It will serve as a general selection guide for those specifying or using such castings.

The bulletin also reviews briefly our experience in both static and centrifugal castings, an experience going back to the pioneering days of 1922 and 1933 respectively. It also tells about our facilities for furnishing castings to any desired analysis, welding, X-ray and gamma ray testing, metallurgical and foundry control.

WRITE or CALL our nearest office for a copy.
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Anodizing and Coloring Aluminum

London, England

In glancing through the January 1959 issue of *Metal Progress*, I noticed a typographical error on p. 89 of the article "Anodizing and Coloring Aluminum in Britain", by Tom Bishop. In Table I the words yellow, green and blue should all be lowered one line so that the green in the first column is opposite dark green in the second column. In the same table, I would also note that the description of the organic blue dyes is more correctly Sandoz Light Blue #1 and Oxanol Blue CB 150%.

F. C. Porter
Metallurgist
Aluminium Development Assoc.

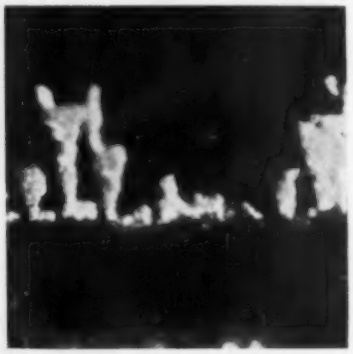
Electrolytic Cactus

Kyoto, Japan

In a series of investigations made on the sharpness of razor blades (*Metal Progress*, March 1954), I tried to sharpen a rough-honed blade edge by electrolytic polishing using a solution of H_3PO_4-CrO_3.

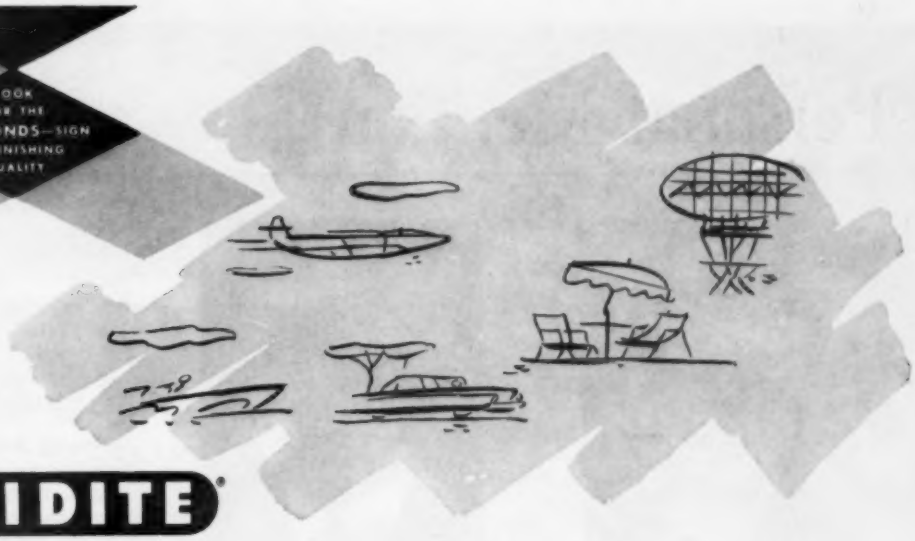
In the case of severe electrolysis (current density of more than 30 amp. per blade), a thin film was left on the blade edge. The film broke off here and there during further electrolysis and the queer remains resembling cactus leaves (see photograph) were produced on the blade edge.

Takao Kawakita
Metallography Laboratory
Kyoto University



"Cactus Leaves" Produced by Electropolishing a Rough-Honed Razor Blade

LOOK FOR THE DIAMONDS—SIGN OF FINISHING QUALITY



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Warehouses located in strategic industrial areas enable us to provide you with fast, economical delivery on any Iridite.

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The superior performance of Iridite provides low final cost by extending operating life and lowering maintenance costs. In addition, Iridite gives you a finish that adds considerably to the value of your product. There's an Iridite to meet every cost and performance requirement.

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If you have an unusual application, we will gladly work with you. Our entire staff of experienced engineers and chemists, and our completely equipped facilities are at your service.

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Personal Mention

Donald E. Nulk

Antonio Scortecci

DONALD E. NULK is in charge of the design metallurgy group of Thompson-Ramo-Wooldridge, Inc., in Cleveland, as senior project engineer. This group, part of the Tapco Group of the company, is responsible for materials and process control of all Thompson originated products while they are in the experimental stage. He was formerly in the Jet Division of the company in a similar capacity and in addition worked on experimental fabrication. Since joining Thompson, Mr. Nulk's activities have centered on materials engineering for new products initiated by development engineering groups, covering a wide variety of metallurgical alloys. Recently he has concentrated on metallurgical materials and processing problems in the aeronautical, missile and nuclear fields, including such areas as thin-walled pressure vessels and turbine devices.

A graduate of Ohio State University, he joined Lincoln Electric Co. in 1946, returning to his studies in 1949 at Pennsylvania State University, where he received a master's degree. After some time at Carnegie Institute of Technology's Metals Research Laboratories, he returned to industry as a resident chief metallurgist of the Des Moines plant of Solar Aircraft Co., where he did work that was instrumental in developing some of the modified processes used in early titanium welding.

ANTONIO SCORTECCI, well known throughout his native Italy and the metallurgical world for his many contributions to the field, has added yet another award to his long list of international honors. He now holds the Le Chatelier Medal of the Société Française de Métallurgie in recognition of his metallurgical achievements.

Professor Scortecci has been director of the Istituto Siderurgico Finsider in Genoa since 1948 when the Institute was founded by a group of companies, the Finsider Group. Under his leadership, the Institute has focused its activities toward three main fields: the selection and professional training of university graduates for the member companies, development of applied research projects through a special system of joint committees, and creation of a documentation service. In the latter field, he has worked closely with ASM; through his efforts the Italian edition of the ASM-SLA Metallurgical Literature Classification System was published, and he is actively promoting this system's acceptance throughout Europe.

Graduating from the University of Florence in 1919, Professor Scortecci began his career as assistant at the University's General Chemistry Institute. Since then he has held supervisory positions in many steelworking companies and, also, since 1936 has taught at the University of Genoa as a lecturer in metallurgy.

His list of society memberships reads like a roster of international metallurgical and technical organizations. These include the Institute of Welding, Société Française de Métallurgie, Verein Deutscher Eisenhüttenleute, and the Italian Association for Metallurgy (where he has served as vice-president since 1946). He has received recognition from several countries and in 1953 was presented with the Cross of the Legion d'Honneur of France.

Eric C. Bell is now a metallurgist in the materials and processes section of Trans-Canada Air Lines in Quebec, Que., Canada.

Frederick J. Winsor recently joined the Foster Wheeler Corp., Carteret, N. J., as manager of the fabrication process development laboratories. He was formerly associated with the engineering department of E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Gerald Pincus, formerly on the research staff of Columbia University, has joined the Materials Research Corp., Yonkers, N. Y., as project engineer.

Thomas J. Connare has joined Standard Steel Works Div., Baldwin-Lima-Hamilton Corp., Burnham, Pa., as metallurgist. He was formerly affiliated with Walworth Co., Greensburg, Pa.

Arthur G. Metcalfe has been named assistant director of research at Solar Aircraft Co., San Diego, Calif., where he will be responsible for advanced research projects. He was formerly connected with the Armour Research Foundation.

Byron F. Campbell is now executive engineer of Ingersoll Kalamazoo Div. of Borg-Warner Corp., Kalamazoo, Mich., where he is assisting in the operation and administration of the company's engineering department.

Robert W. Adams was recently appointed manager of wire sales for Aluminum Co. of America, Pittsburgh. Mr. Adams joined Alcoa in 1947 after graduation from the Alabama Polytechnic Institute and served for almost 12 years in the Atlanta sales office.

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Personals . . .

Richard C. Tonner, section head at the Woburn, Mass., plant of Sylvania Electric Products, Inc., since 1957, is now manufacturing superintendent of the semiconductor plant there.

Walter H. Wooding, former civilian head of the Industrial Test Laboratory at the Philadelphia Navy Yard, has joined Arcos Corp., Philadelphia. His background includes 20 years at the Industrial Test Laboratory as plant control metallurgist, superintendent of the metals section, and finally civilian head of the entire laboratory.

A. T. Richter has been promoted from Pittsburgh district sales manager to assistant general sales manager of the Midvale-Heppenstall Co., Philadelphia. Mr. Richter, who joined the former Midvale Co. in 1936, transferred to the sales department in 1948.

George A. Roberts, vice-president, technology, Vanadium-Alloys Steel Co., Latrobe, Pa., was recently re-elected president of Metal Powder Industries Federation at the association's annual meeting in Detroit. At the same time, **Kempton H. Roll** was re-appointed executive secretary and treasurer. The Powder Metallurgy Equipment Assoc. division of MPI elected **Norbert K. Koebel**, Lindberg Engineering Co., and **Clemens C. Sutinen**, Mannesmann-Meer Engineering & Construction Co., as new directors.

H. C. Child, research manager of William Jessops and Sons, Ltd., Rotherham, England, has been awarded the Williams Prize for 1958 of the Iron and Steel Institute for a paper on "Vacuum-Melting of Steels", which appeared in the *Journal* of the Institute.

Robert B. Gordon has been appointed deputy director, fuels and materials, for Atomic International Div., North American Aviation, Inc., Canoga Park, Calif.

E. T. Walton has been appointed director of metallurgy for the Crucible Steel Co. of America, Pittsburgh. He will continue to hold his former position as manager of customer technical services, a post he has held since 1958.

Marvin L. Duggins has been appointed branch manager of the St. Louis territory of the Carpenter Steel Co., Reading, Pa. Mr. Duggins, who joined Carpenter in 1953, assumes responsibility for sales management in the St. Louis territory in addition to management of the firm's branch warehouse there.

Arch T. Colwell now occupies the newly created position of vice-president, engineering, research and development, at Thompson Ramo Wooldridge, Inc., Cleveland. In addition to the investigation of new products, he will provide liaison among the various TRW divisions, including Pacific Semiconductors, Inc., and Thompson - Ramo - Wooldridge Products Co.

Keith M. McElwain, active in the powder metallurgy industry since 1945, recently accepted an appointment as iron powder technical sales representative for the eastern district of Alan Wood Steel Co., Conshohocken, Pa. Mr. McElwain, formerly associated with the Bassick Co., Bridgeport, Conn., will have his headquarters in Fairfield, Conn.

Robert L. Marshall is now at the head of a new sales engineering organization known as Dyna-Sales Co. in Los Angeles. Since coming to Los Angeles in 1948, he has been employed by Westinghouse Electric Corp., Weston Instruments Div. of Daystrom Inc., and Consolidated Electrodynamics Corp.

Charles E. Hanson has been elected to succeed **Ernest H. Klein** as president for 1959-60 of the Metal Powder Producers Assoc., a trade division of the Metal Powder Industries Federation. Mr. Hanson is affiliated with Plastic Metals, a division of National-U. S. Radiator Corp., while Mr. Klein is employed with the New Jersey Zinc Co.

A. F. Chouinard, director of research and development, National Cylinder Gas Co., was elected vice-president of the American Welding Society at the organization's annual meeting in Chicago. At the same time, **R. D. Thomas, Jr.**, president of Arcos Corp., was elected first vice-president and **J. R. Stitt**, research and welding engineer for R. C. Mahon Co., was elected director-at-large.

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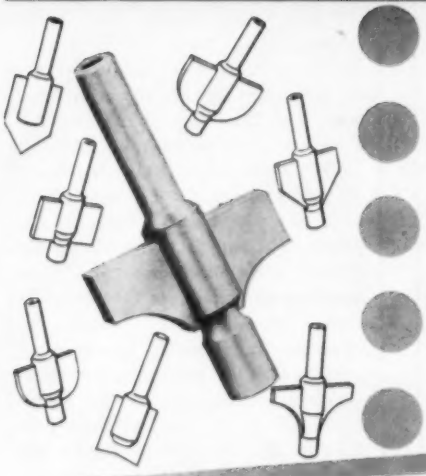

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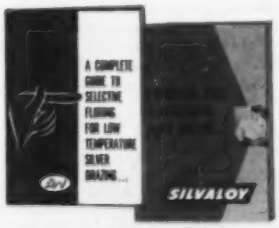

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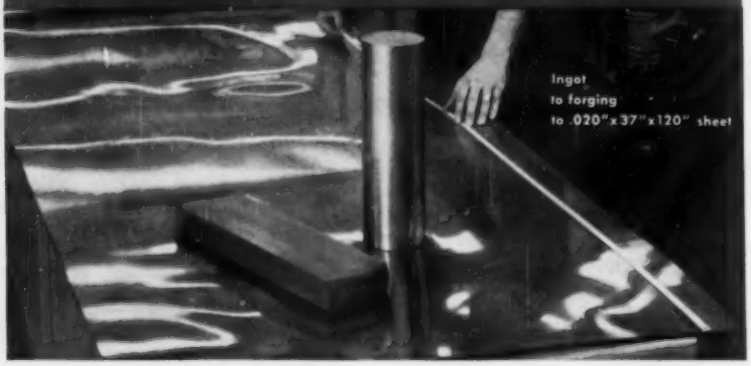

FANSTEEL 80 METAL

Alloy—Columbium-zirconium

Melting Point—4350°F.

Density—
8.6 grams per cc (0.311 lb. per cu. in.)

Tensile Strength—
Annealed 70°F.; 47,000 psi.

Stress-To-Rupture—
100 hr. 2000°F.
(argon) 18,800 psi.
500 hr. 2000°F.
(argon) 11,000 psi.

Other Properties—Ductile to brittle transition temperatures in annealed state are well below room temperature.

Advantages and Uses—Extremely high strength-to-weight ratio for high temperature applications. Excellent weldability, ductile welds with little or no tendency to fracture in heat affected zones. Easy fabrication at room temperature, as worked or annealed. For missiles, rockets, spacecraft, other high heat applications.

FANSTEEL 82 METAL

Alloy—Columbium-tantalum-zirconium

Melting Point—4550°F.

Density—
10.26 grams per cc (0.371 lb. per cu. in.)

Tensile Strength—
Annealed 70°F.; 55,000 psi.
2000°F. in air; 29,600 psi.
2400°F. in air; 11,700 psi.

Stress-To-Rupture—
100 hr. 2000°F. (argon) 17,500 psi.
500 hr. 2000°F. (argon) 13,500 psi.

Other Properties—High oxidation resistance compared to pure refractory metals. Oxide film is tenacious, non-volatile, tends to form protective coating. 16-hour, 2000°F. tests in flowing air show remarkably low scaling of 0.01 cm.

Advantages and Uses—Exceptionally suitable for air-frames and certain missile applications. Provides desirable strength-to-weight advantages at higher temperatures plus the same workability, weldability and ductility of Fansteel 80 Alloy.

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Personals . . .

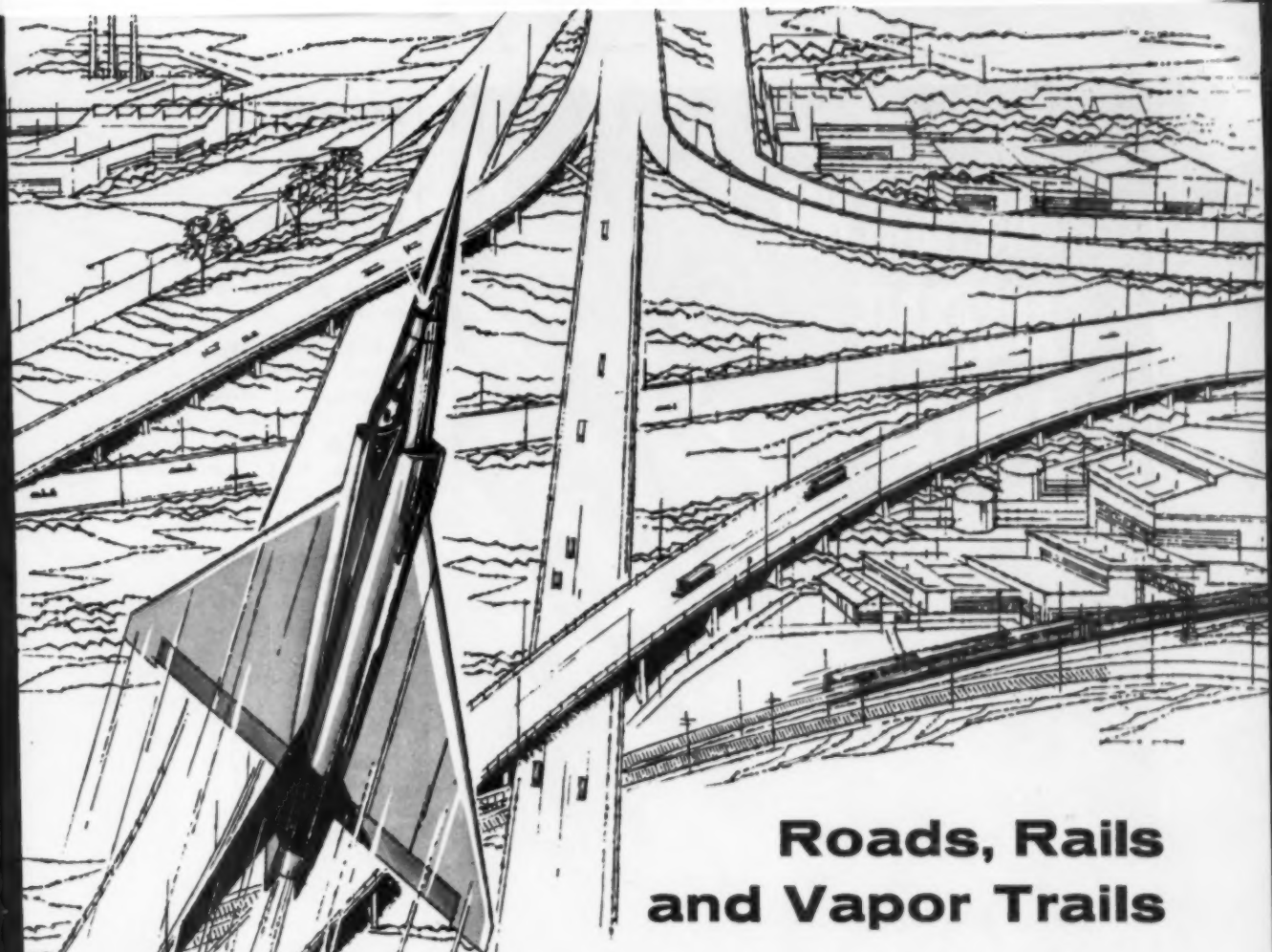
Max Dupont has been named secretary general of the Société Française de Métallurgie in Paris.

W. G. Wood was appointed a director of Park Chemical Co., Detroit, at the annual stockholders meeting recently. He was also elected vice-president in charge of research and laboratory control.

Fred W. Drosten, former reactor engineer with the U. S. Atomic Energy Commission's Oak Ridge Operations Office, has joined Heavy Minerals Co., Chattanooga, Tenn., a subsidiary of Vitro Corp. of America, as director of metallurgical development. Before going to Oak Ridge, he had been a section head with the development staff of Cramet, Inc., Chattanooga, Tenn., and prior to that served as research director of the Nickel Processing Corp., Nicaro, Cuba, for several years. A member of the Chattanooga Chapter, he was one of the founders of the Society's Oak Ridge Chapter.

Integration of their district offices in Chicago, Cleveland, Detroit, Pittsburgh, Schenectady and Washington, D.C., has been announced by Heppenstall Co. and its wholly owned subsidiary Midvale-Heppenstall Co. Each of these offices will function as a single sales unit for both companies. **James R. Steele** will manage the Chicago office, assisted by **Robert L. Kofmehl**. **Harry O. Lang** will manage the Detroit office, with **John W. Hammarberg** and **James C. Patton** under his direction. **George H. Wurster**, formerly manager of forging and die steel sales for Heppenstall, is manager of the Pittsburgh office, assisted by **Charles B. Coburn** and **Edwin Pfeifer**. In Washington, D.C., the manager will be **R. H. Romig**.

George M. Thomas has been appointed development metallurgist in the materials laboratory of the Owego, N. Y., plant of the International Business Machines Corp. Joining IBM in 1954 at the Endicott, N. Y., metallurgical laboratory, he became staff metallurgist in 1956 assigned to production engineering in Owego. He last served as project metallurgist.



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Whether it hugs the earth or rides the stratosphere's jet streams, **modern** transportation has one **un**common denominator—stainless steel.

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Every American auto on the road today uses stainless steel functionally and decoratively to protect painted and treated surfaces, because only stainless steel requires no protective treatment to preserve factory freshness and assure lasting customer satisfaction. **And** its unusual workability means that finished product costs are usually lower than for any other bright metal.

Whether your primary interest is function or form, J&L provides **consistent** quality for uniform production.

J&L leads the industry in melt shop standards for stainless steel—the point where quality starts, **and production economies begin.**

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BEAVER FALLS · PENNSYLVANIA

Personals . . .

R. L. Hugo was recently appointed product representative, sheet mill products division, for Jones & Laughlin Steel Corp., Pittsburgh. Prior to this position, he was employed in J&L's cold finished bar division.

Richard W. Nuffort has been elected vice-president and treasurer of Whitehead Metals, Inc., New York. Concurrently, **Edmund L. Carey**, manager of Whitehead's Harrison, N. J., branch, has been elected to the additional post of secretary of the company.

Sidney Metzger has joined the manufacturing staff of the Brush Beryllium Co., Elmore, Ohio, as rolling mill superintendent of the alloy division. For the last nine years, he has been process engineer with W. B. Driver Co., Newark, N. J.

John C. Redmond, former vice-president in charge of metallurgical research and development for Kennametal, Inc., has assumed the post of director of research at Firth-Sterling, Inc., Pittsburgh.

Harper D. Roth has been elected vice-president in charge of marketing of Harper Electric Furnace Corp., Buffalo, N. Y. Joining Harper in 1950, he has been treasurer since 1954. **George A. Chutter**, Harper's representative for the New England and eastern New York area since 1946, was elected a director.

Howard H. Wilder, manager, engineering sales, Vanadium Corp. of America, Chicago, has received the 1959 Award of Scientific Merit of the American Foundrymen's Society "for noteworthy contributions to the Society and its membership in furthering the technology of ferrous castings and their acceptance".

Ross Holmes recently joined the staff of Hoeganaes Sponge Iron Corp., Riverton, N. J., as manager of the pre-mix department which offers blended powders ready for the fabricator's presses. His last position was as section engineer of the development, process and control laboratory, powdered metals operation, of the Ford Motor Co. in Ypsilanti, Mich.

a tiny milling cutter

a broach of

largest size

the **quality**

is identical

because the **steel**

is **VANADIUM-ALLOYS**

Photo Courtesy National Broach & Machine Co.

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- Vasco M-2
- Van Lom
- Red Cut Superior
- Neatro
- Van Cut
- 8-N-2

FIRST QUALITY has a diamond-clear meaning when applied to our steels. It is a term expressing guaranteed excellence in a ⅜" bar from which thousands of miniature milling cutters are made—and equally in a bar from which may be machined the largest broach you care to produce. Sound steels for profit-making tools, in a complete range of grades, shapes and sizes. Let a Vanadium-Alloys' sales engineer consult with you on your needs.

V·A

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LATROBE, PENNSYLVANIA

DIVISIONS: Anchor Drawn Steel Co. · Colonial Steel Co. · Metal Forming Corporation · Pittsburgh Tool Steel Wire Co. · **SUBSIDIARIES:** Vanadium-Alloys Steel Canada Limited · Vanadium-Alloys Steel Societa Italiana Per Azioni · EUROPEAN ASSOCIATES: Societe Commentryenne Des Aciers Fins Vanadium-Alloys (France) · Nazionale Cogne Societa Italiana (Italy)

For economical under-paint protection

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These two panels were identically painted, scored with an "X", and exposed to salt spray test for 480 hours. The difference: the one on the right was first treated with an Oakite CRYSCOAT iron phosphate conversion coating.

This painted tubing was CrysCoated. Repeated punching did not break paint grip despite severe abuse and deformation.

Oakite CRYSCOAT® iron phosphate coatings cut the cost of corrosion-protection

You get proper protection *plus* economy with CrysCoat iron phosphate coatings.

First of all, they lock paint to steel, giving a superior paint grip under bending stresses. Bend tests show less chipping and flaking of paint. And note how paint held tight even at punched holes in the sample above.

Secondly, they keep corrosion from spreading at every scratch, as the panels above show so graphically.

But most important, they save money. Because CRYSCOAT iron phosphate processes *clean* as they phosphate. Because you need only a three-stage washer. Because *no* acid-proof equipment is required. You save both on equipment and production time. In addition, the smoother iron phosphate coatings soak up less paint than coarser phosphate coatings . . . giving you a sleek finish with one less coat.

It will pay you to *ask Oakite* about phosphating. You'll find the right one for *your* requirements in the complete CrysCoat line which includes both zinc and iron phosphate processes, for spray or tank, for room or elevated temperature operations. Meanwhile, write for Bulletin F-9475. Oakite Products, Inc., 26H Rector Street, New York 6, N. Y.

it PAYS to ask Oakite

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50 1909-1959 SCIENCE

years' leadership in industrial cleaning

Personals . . .

Alexander Gobus, product manager of the industrial radiography department, Philips Electronics, Inc., Mount Vernon, N. Y., received the Noah A. Kahn Memorial Award for 1959 from the Metropolitan Chapter of the Society for Nondestructive Testing in recognition of his many contributions to this field.

Charles E. Nelson, technical director of the magnesium department of Dow Chemical Co., Midland, Mich., was elected president for 1959-60 of the American Foundrymen's Society at the organization's annual business meeting in Chicago. Another ASM member, Howard W. Lownie, Jr., division chief, Battelle Memorial Institute, Columbus, Ohio, was honored by the Society. Mr. Lownie was awarded the John H. Whiting Gold Medal "for outstanding contributions to the Society and to metallurgical progress, especially in the field of gray cast iron.

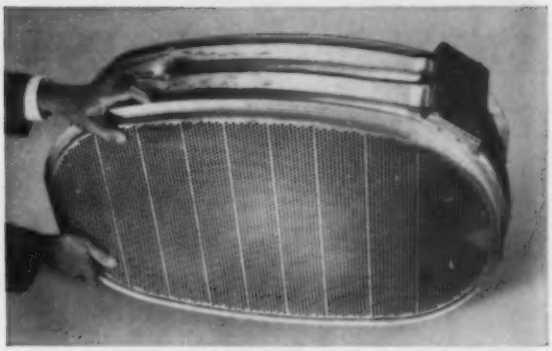
Robert E. Herbert, a metallurgist for four years at Vanadium-Alloys Steel Co., Latrobe, Pa., has been named manager of the company's new vacuum melting department. At the same time **C. J. Stalnaker** has been assigned to the department as product metallurgist.

Earl L. Richards has been named a senior process engineer for Mallory-Sharon Metals Corp., Niles, Ohio. Before coming to Mallory-Sharon, he was associated with Westinghouse Atomic Power Div. in Pittsburgh, engaged in work related to submarine and nuclear power reactors.

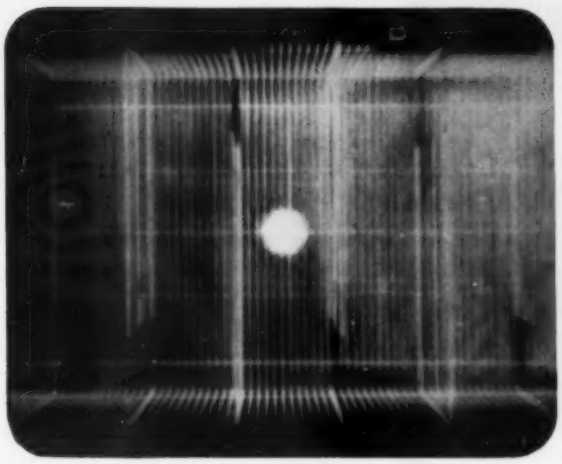
Robert A. Kokat has been promoted to district manager of the Philadelphia sales territory for Carpenter Steel Co., Reading, Pa. Prior to his promotion, he held the positions of salesman, assistant branch manager and branch manager of Carpenter's Philadelphia warehouse.

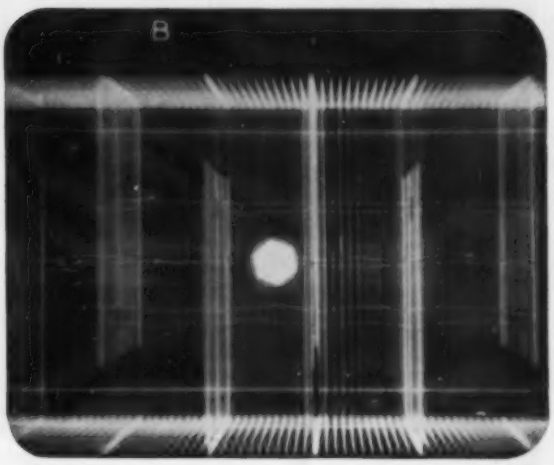
Howard B. Myers has been elected a vice-president of Tenn-Tex Alloy & Chemical Corp., Houston, Tex., a subsidiary of Tennessee Products & Chemical Corp., Nashville, Tenn. He will also continue to serve as sales manager of alloys and metals for the parent company.

An oil cooler as it comes from the airplane engine. Radiograph below shows accumulations of sludge and dirt on the tubes.



After cleaning, the oil cooler is ready to return to its job. Radiograph below shows dirt gone and passages unrestricted.





To keep an engine's bloodstream clean

Oil coolers are vital to today's aircraft engines. At overhaul time they must go back on the engine clean as new. No minute particles of carbon or metal can remain to be a threat to the renewed engine. Cleaning them has become a specialty with SMS Instrument and Accessories Corp. of Idlewild Airport, N. Y. C.

To show that each cooler they clean is free of debris, it is sent to Industrial X-ray Incorporated, New Hyde Park, New York, to be radiographed. And when the cooler goes back to its job, its x-ray certificate of cleanliness goes with it.

In such inspections of assemblies, in quality control, in nondestructive testing, radiography provides a means of "seeing" internal conditions and also a lasting record of what is seen.

Producers of castings, and makers of welded products, find radiography a means of expanding their business and making sure only high-quality work is delivered.

Would you like to learn how it could help you? Contact your Kodak x-ray dealer or the Kodak Technical Representative to talk it over.

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The casting above was Rotoblast cleaned at new low cost made possible by Rotoblast Steel Shot. Although cleaning cost per casting may seem a small part of your overall production cost, its efficiency often spells the difference between big and small profits on the finished job. Rotoblast assures you *maximum profit.*

Why? Because Rotoblast shot starts as a better-made steel, low in phosphorus and sulphur, produced in modern electric furnaces. Because Rotoblast shot uses an exclusive casting method to produce solid shot. Because Rotoblast is continuous-heat treated in a controlled atmosphere — another exclusive — to give you uniformity and the right hardness for fast cleaning *and* long wear.

Prove Rotoblast's cost-cutting qualities in *your* plant. To arrange a test, talk to your Pangborn man or write PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Maryland. *Manufacturers of Blast Cleaning and Dust Control Equipment— Rotoblast® Steel Shot and Grit.*

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ROTOBLAST STEEL SHOT AND GRIT

Personals . . .

John A. Rassenfoss, manager, manufacturing research laboratory, American Steel Foundries, East Chicago, Ind., has received the Peter L. Simpson Gold Medal of the American Foundrymen's Society "for exceptional contributions to the Society and the steel castings industry, by elevating technical endeavor in steel foundry research". The Society's John A. Penton Gold Medal was awarded to **Fred J. Walls**, vice-president, research and development, Engineering Castings, Inc., Marshall, Mich., "for outstanding contributions to the Society and the castings industry, especially in gray iron metallurgy and foundry practice, and for lifetime devotion to the industry's potentialities".

Donald F. Brookland has been elected vice-president for alloys of Tennessee Products & Chemical Corp., Nashville, Tenn. Prior to joining the company, he was associated with Keokuk Electro Metals, Keokuk, Iowa, for five years, recently as vice-president for operations.

E. F. Nippes, professor of metallurgical engineering and director of welding research at Rensselaer Polytechnic Institute, was awarded the Samuel Wylie Miller Memorial Medal by the American Welding Society for "meritorious achievement in advancing the art of welding and cutting". Other AWS awards presented at the Society's annual meeting in Chicago included the J. F. Lincoln Gold Medal, awarded to **Alexander Lesnewich** supervisor of welding research for the Air Reduction Co., and the A. F. Davis Silver Medals awarded to **John Mikulak**, assistant to the vice-president of manufacturing, Worthington Corp., **L. V. LaRou**, vice-president of engineering, Wall Colmonoy Corp., Detroit, and **K. H. Koopman**, executive director of the Pressure Vessel Research Committee of the Welding Research Council.

Lawrence W. Collins, Jr., has been named an account executive of the Manning Public Relations Firm, New York. Mr. Collins' past experience includes many years as executive editor and managing editor of *Metalworking*.

James H. Moore is a new member of the board of directors of National Research Corp., Cambridge, Mass. Mr. Moore is vice-president of the company and general manager of NRC Equipment Corp., a wholly-owned subsidiary of National Research.

Robert L. McGlasson has been promoted to senior research metallurgist in the production research division of Continental Oil Co., Houston, Tex. Prior to joining Continental, he was employed by Boeing Airplane Co., Wichita, Kan.

Theodore W. Bossert has just been elected to the post of vice-president of the Aluminum Co. of America, Pittsburgh. He came to Alcoa in 1923 as a graduate of Massachusetts Institute of Technology, serving in metallurgical and research posts before being named chief company metallurgist in 1956. Last year he was appointed chairman of the reorganized and expanded research and development committee.

W. O. Owen, who for many years has specified and handled special furnaces built by Surface Combustion Corp., has joined the staff of Natural Gas Equipment, Inc., representatives of Surface Combustion in California and the West.

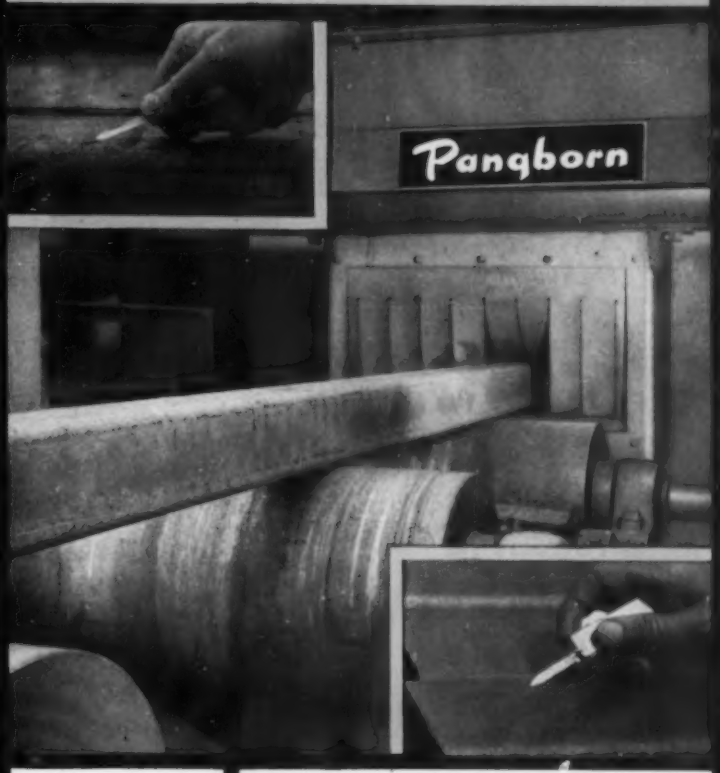
C. Robert Derhammer, formerly vice-president of the Lakeside Steel Improvement Co., Cleveland, has been elected president. **John H. Ries** was appointed executive vice-president and treasurer.

D. W. Mills is now sales manager of Composite Forgings, Inc., of Detroit.

Lewis A. Wible was recently elected executive vice-president of Union Electric Steel Corp., Pittsburgh. He has been with the firm for a number of years and has been vice-president of sales, and secretary; he will continue to hold the post of secretary.

Al Thurman has been named president of the Lombard Mfg. Co. and vice-president of Lombard Corp. with headquarters in Youngstown, Ohio. For the past several years, he has been a management consultant and consulting engineer to heavy industry from his office in Huntington, W. Va., and he will continue to maintain his consulting office.

GIVES "JUST RIGHT" DESCALING!



Large steel producer uses Rotoblast descaling for exact cleaning quality

To facilitate inspection for flaws, one of the country's leading steel producers cleans ¾-ton billets with a special Rotoblast descaling machine. Because cleaning time depends on the varying steel composition of the billets, this machine is equipped with six speed settings. According to company supervisors, the quality of Rotoblast cleaning is "just right" . . . all loose scale is removed for easy inspection without overblasting to peen over and hide flaws. What's more, Rotoblast operation is reported to be efficient, dependable and trouble-free.

If you have a standard or special descaling problem, your solution is Pangborn Rotoblast. Ask the Pangborn man in your area or write PANGBORN CORP., 1800 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment — Rotoblast Steel Shot and Grit.*

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Metal Powders for Missile Fuels

Digest of "Metal Powders in Missile and Rocket Fuels," by L. R. Frazier, Metal Hydrides, Inc., Beverly, Mass. Paper presented at Indiana ASM Chapters 11th Annual Symposium, Purdue University, April 1959.

WHAT particular properties do some metals have that make them suitable as possible rocket fuels? Certain metals are light in weight and are capable of supplying large quantities of energy or heat as they are burned to oxides in a rocket motor combustion chamber. Table I shows several of the more energetic of these oxide formers.

The generation of energy is the first requirement of a rocket fuel. From this standpoint, beryllium and lithium, the first two metals listed in Table I, might appear to be the ideal rocket fuels; however, since they are both comparatively rare, four of the next group of five elements listed (boron, aluminum, magnesium and hydrogen) have come into wider use as the rocket and missile fuel materials. Boron is used in the super fuels in combination with other elements such as hydrogen and carbon.

Physical Form – Fuel produced for a rocket motor must be in a physical form suitable for feeding to the motor and for combustion. Perhaps the simplest approach is to slurry a powder of boron, aluminum or magnesium in a hydrocarbon oil. Dispersing agents, such as metallic soaps, are used to prevent solid particles from settling out of the oil. Other approaches have been tried, such as combining several of the elements into compounds which may be more suitable for mixing with liquid hydrocarbons. The fuel combinations discussed so far are those designed for liquid injection along with liquid oxygen or nitric acid. The liquid fuels are most likely to be used in the larger rockets and missiles. The best relationship between fuel weight and energy can be obtained in this type of fuel.

Table I – Energy Available Through Oxidizing Metals

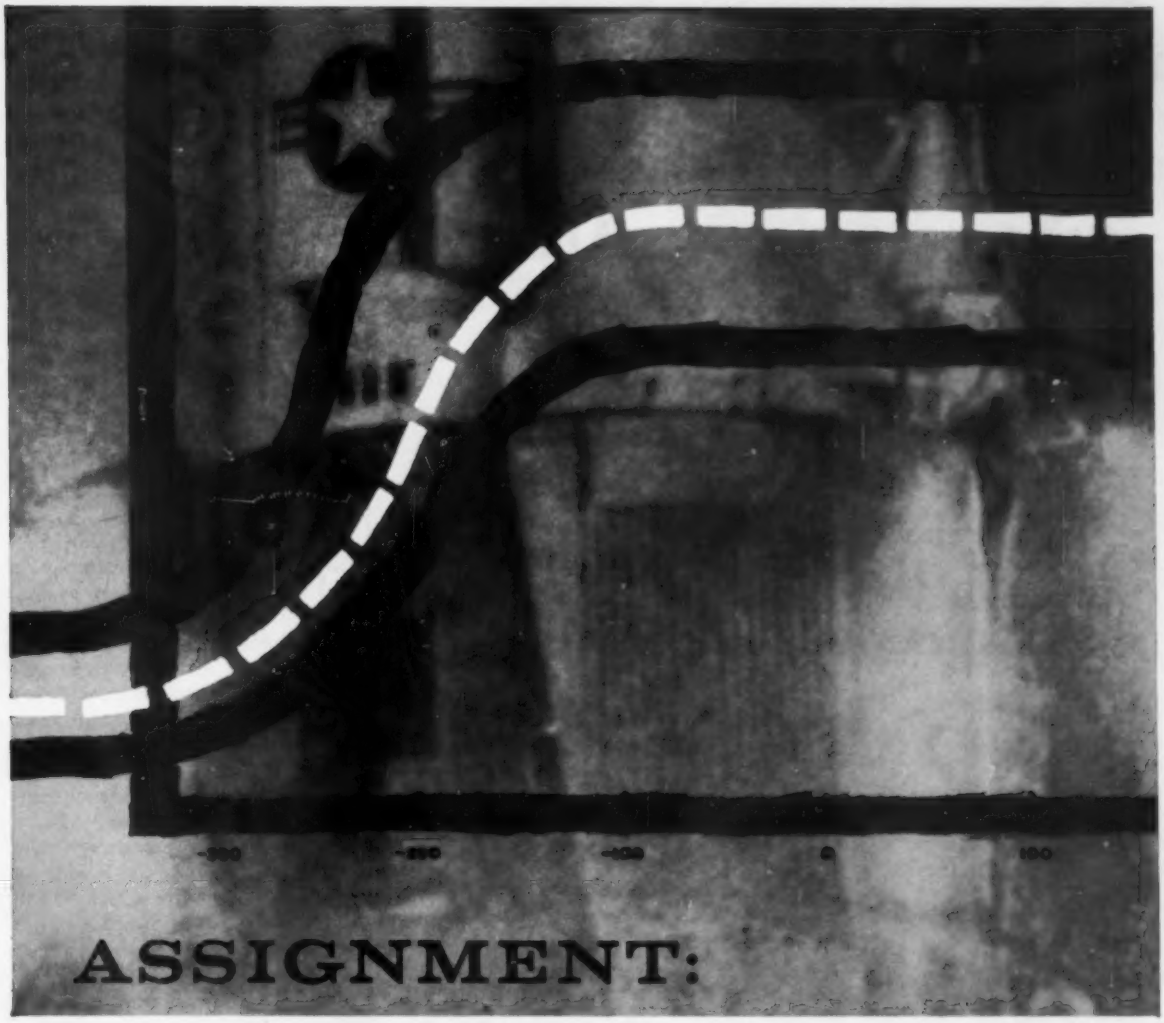
Metal	After Oxidation	ΔF at 298°★
Beryllium	BeO	5450
Lithium	Li_2O	4480
Boron	B_2O_3	4070
Aluminum	Al_2O_3	3580
Magnesium	MgO	3380
Silicon	SiO_2	3270
Hydrogen	H_2O gas	3130
Scandium	Sc_2O_3	2820
Titanium	TiO_2	2660
Phosphorus	P_4O_{10}	2305
Carbon	CO_2 gas	2142
Iron	Fe_2O_3	1110
Zinc	ZnO	937
Nickel	NiO	678
Copper	CuO	244

★In kg-cal. per g.

Solid Fuels – There is another group of fuels more commonly used in smaller rockets, booster motors, and pyrotechnics. These are the solid fuels which are generally used with solid oxidizing agents. The advantage of the solid fuels is that they require no auxiliary equipment in the form of pumps and controls. The burning rates of the solid fuels can be controlled by their textures and compositions.

The solid fuels can readily use metal powders such as aluminum, boron, magnesium, titanium and zirconium, since they stay mixed with the oxidizing agents until they are burned. Disadvantages of the solid fuels are their lower energy per unit weight, their tendency to be unstable in storage unless protected by resin additives, and their lack of definite cut-off time and inability to re-ignite.

Requirements of metals for missile and rocket fuels include high energy, light weight, physical control, physical stability, chemical stability, abundance, generation of gas and minimum residue. Light weight is important; the fuel designer must minimize the wasted energy of using fuel to lift fuel. Rocket fuels also require physical controlability. Obviously, gases such as hydrogen, unless put under very high pressure, are too bulky. A small rocket could not contain enough hydrogen to be used as its single fuel. Metal powders have the advantage over



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How Lukens *Application Research* helps you find the right steel plate for the job

If your assignment is designing equipment for extreme low temperature service—our Application Engineering staff can help you. They research problems of every description from the design stage right through to how the equipment has performed for years after its installation.

Missile components and liquefied gas tanks would be dangerously susceptible to cracking if made from ordinary steel. Seeking economical metals for such applications, Lukens engineers began years ago to watch the performance of nickel bearing alloys in a variety of low temperature equipment. Result: a broad understanding of metal behavior at various low temperature levels.

Examples: In the storage of liquefied oxygen, a tank of *Nine Nickel steel* provided more than eight years of trouble-free performance. Suitable to minus 320°F. service the steel showed no signs of cracking when removed for inspection. In frigid chambers for testing high altitude aircraft, *2½ percent nickel steel* is standing up well under pressures as high as 7,000,000 pounds. And in arctic locomotives operating at temperatures to minus 50°F. on rugged mountain roadbeds, main structures of *Lukens "T-1" Steel* have required no maintenance whatsoever.

Lukens Application Engineers know these cases . . . plus many more. *If your assignment is cryogenics, why not let it be our assignment, too?* Contact Manager, Application Engineering, F-79 Services Building, Lukens Steel Company, Coatesville, Pa.

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there's more than meets the eye

In these "LONG JOHN" Muffle Tubes

Even Rolock's welded-fabrication experts consider these 32-foot Inconel muffle tubes an exacting test of skill. The inset sketch shows how they are made, and the dimensions . . . 32 feet long by only 5½ inches O.A. width and 1 inch inside height . . . leave little room for any inaccuracy. These muffles . . . used for continuous bright annealing of steel strip . . . just *have* to be straight and true when installed, and stay that way in service.

We produce these muffle tubes "by the dozen" for use by the steel strip mills in gas-fired furnaces. Upper and lower sections are assembled separately with diagonal joints welded inside and out. The full length sections are then edge-welded together. Tight specifications call for no weld-splatter on the inside, and each tube is pressure-tested to 25 lbs. p.s.i. before shipment. This is another example of Rolock service to key industries in building and designing many forms of special equipment that modern production processes call for.

If you have a problem in welded-fabrication of high heat and corrosion-resistant alloys, it will pay you to consult Rolock . . . the nationally recognized *specialists* in this field.

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Easier Operation, Lower Cost

BRL57

Metal Powders . . .

hydrogen, carbon monoxide or methane in that they occupy much less space within the rocket.

Dispersing Mechanism – Massive solids (such as a block of magnesium) cannot be used as rocket fuels, since they are not dispersable for mixing with oxygen. Very fine metal particles offer better performance. However, even dry powder metals need a dispersing mechanism. The powder might possibly be thrown into the stream of oxygen. The particles might be blown in by a gas such as hydrogen, or they might be premixed for injection in a liquid vehicle such as a light hydrocarbon oil or kerosene.

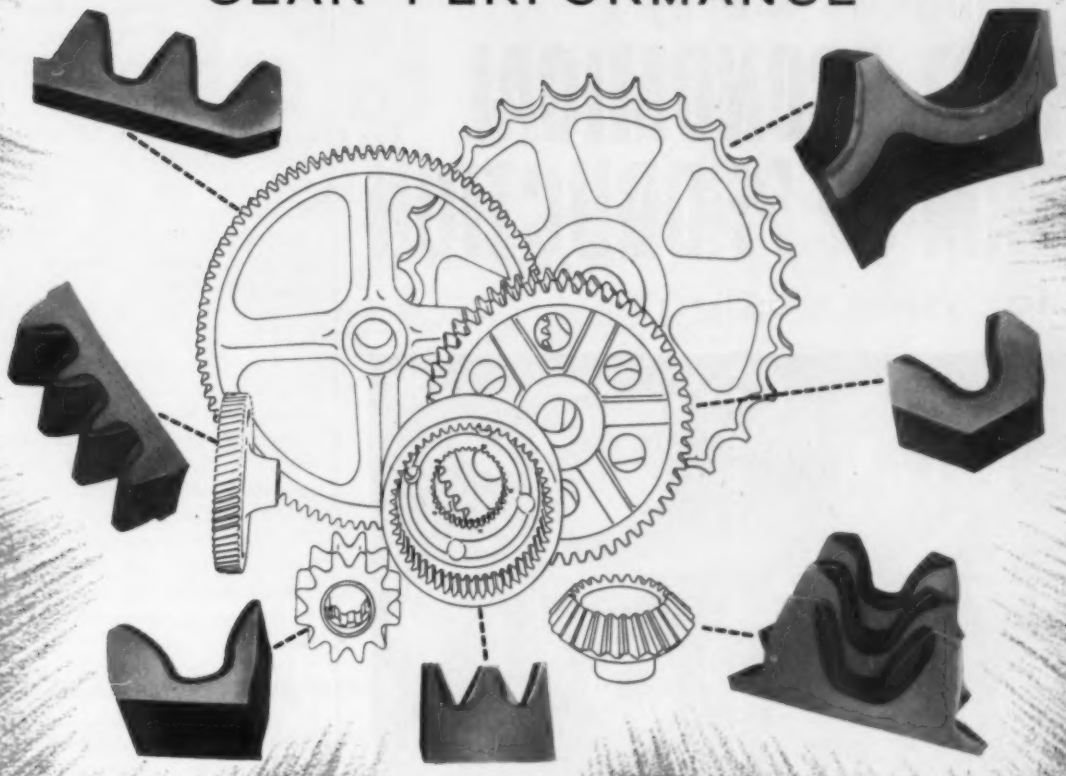
The dispersing mechanism is not required where the metal powder has been premixed with an oxidizer and binder for use as a solid fuel. The liquid containing the suspended metal powder also must pass through pumps and injection nozzles. Fineness and wetting characteristics of the powder must be considered in developing a suspension-type fuel.

High-Velocity Gases – Rocket fuels must generate gases. Forces developed by the fuels depend upon the gases expanding and leaving the combustion chamber at high velocity through the exhaust nozzle. Hydrogen and carbon are the best gas formers. Although some of the metal oxides vaporize at high temperatures of combustion, they are likely to be cooled to liquids or solids by radiation of the heat to the surroundings.

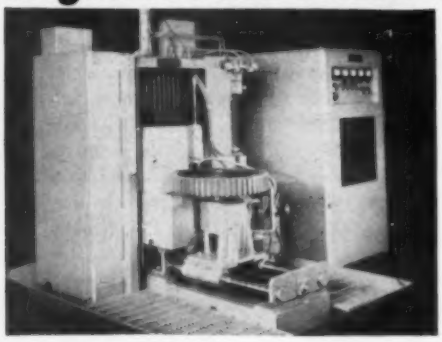
Solid metal particles burning to solid oxide particles, while they develop very high temperatures, would not expel themselves from the combustion chamber without the gas-forming materials. The energy released by the combustion of the metal particles, however, can aid in heating the gas and accelerating the expulsion from the chamber, thereby increasing the rocket force.

Residue Must Be Avoided – A rocket fuel must leave a minimum of residue on the combustion chamber and exhaust nozzle walls. Oxides collecting on rocket nozzles interfere with performance. There are several reasons for this. Liquid oxides are sticky and corrosive in some cases. Solid oxides build up and change the shape of gas passages.

PATTERNS FOR IMPROVED GEAR PERFORMANCE



Magnethermic Induction Scanner Heat Treats 6" to 60" Diameter Gears at... SURPRISINGLY LOW COST



Tooth by Tooth Gear Machine, a product of the Magnethermic Division

All kinds of savings with this Magnethermic method . . . low power and limited initial investment. Improved physical properties, particularly in the critical root zone, in many cases allow use of smaller gears or change-over from expensive alloy steels to plain carbon grades.

Distortion minimized with only a small part of the gear heat affected; no over-all compressive forces.

Flexibility of scanning makes inductors applicable to varying face widths, machine adaptable to many gear types, plus sprockets.

With automatic indexing, attention is confined to loading and unloading . . . cumulative positioning errors are eliminated.

These advantages have been proved in actual installations.

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Your Ampco field engineer is not limited to a single copper-base alloy or a single form, in making recommendations. He can be completely impartial, because Ampco supplies them all.

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6-21

AMPCO METAL, INC., Dept. 20G, Milwaukee 46, Wis.

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Metal Powders . . .

For example, rocket nozzles extend their throats, jet engine blades lose their foil shape, and valves and walls of internal combustion engines become coated.

Flammability – To be useful in rocket fuels, metal powders must be flammable. Some metals are more flammable than others. Among the more flammable ones are uranium, zirconium, thorium, aluminum, magnesium and titanium.

However, composition is not the only factor in flammability. Small particle size is important, too. This is because flammability is dependent upon available surface for the chemical reaction of uniting the metal with oxygen. Available surface for this reaction varies in inverse proportion to the particle diameter. A particle of 1 micron diameter, for example, has about ten times the available surface compared to a particle of 10 microns diameter, relative to its mass.

Uranium at about 15 microns particle size will ignite spontaneously in air. Zirconium, commonly thought to be quite dangerous, must be reduced to 3 microns to be spontaneously ignitable. Tungsten becomes comparably flammable at about 1 micron. Iron, nickel and copper are not immune to spontaneous ignition; particles 0.03 micron in size have been found to be spontaneously combustible.

Particle Size – Propagation of combustion in a metal powder ordinarily does not require as fine particle size as initial ignition; therefore, a powder containing a wide range of sizes may be spontaneously ignitable even when the average particle size is much higher than the figures above and when only 10% of the powder is at the sizes noted above. Distribution of particle size is, then, very important both for ignition and a uniform burning rate.

Fine particles can be reduced in flammability by partial oxidation. This is prevented by collection of the fine powders as they are prepared in a hydrocarbon such as hexane or in inert gas. Even when stored in a gas such as helium or argon, fine powders deteriorate with age and gradual oxidation.

Other Uses – Ordnance items such as photoflash powders, flares and

Trenton 5, New Jersey | Youngstown 1, Ohio | Trenton 7, New Jersey

Two of nine Ipsen controlled atmosphere, semi-automated heat treating units used by Fuller Manufacturing Company (a subsidiary of Eaton Manufacturing Company), Kalamazoo, Michigan

"We've increased production with our seven Ipsen Furnaces."

Fuller Manufacturing Company
—a subsidiary of Eaton Manufacturing Company

George M. Travers is Chief Metallurgist of Fuller Manufacturing Company (a subsidiary of Eaton Manufacturing Company), Kalamazoo, Michigan, a well-known producer of heavy duty transmissions for manufacturers of trucks and tractors. In the following interview, Mr. Travers tells why he is pleased with his Ipsen equipment.

Q. During the last eight years you have bought a number of Ipsen controlled atmosphere, semi-automated heat treating units, and related equipment, for carburizing applications. What type of work do you normally carburize in this equipment?

A. We use your equipment mainly for deep case carburizing of heavy section gears and countershafts for our "Road Ranger" transmissions. We also carbonitride power take-off gears, shifting forks, and washers where we need file hardnesses. Our first Ipsen furnace and generator were installed in 1951. In 1955, we added three large, double chamber, semi-automated units and a draw furnace. Then again the following year, we installed three more similar units and another draw furnace. We also use Ipsen atmosphere generators and Dewtronik equipment.

Q. Does your Ipsen carburizing equipment replace other types of equipment?

A. It supplements large, multiple-row furnaces used for routine carburizing. The Ipsen units give us greater latitude in choice of cycles, carbon concentrations, and case depth characteristics.

Q. Have you been able to increase production with your Ipsen equipment?

A. Yes . . if you mean increased production per square foot of floor area, or decreased over-all time of treatment. Also, we find that when it is necessary to increase or decrease heating or holding time for different parts, we can do it much easier and faster in the Ipsen forced convection equipment.

Q. What about your maintenance costs?

A. Your furnaces have a minimum of alloyed parts subjected to heating and carburizing conditions, and the life of conveying trays has been good. The vertical ceramic heating tubes are easy to replace. And they do not bend or sag during operation. Maintenance cost, per pound of work treated, for our Ipsen equipment is comparable . . perhaps lower than for our bigger furnaces. Your equipment is easier to maintain. Another advantage is that with several smaller Ipsen furnaces, we can shut down one for maintenance without completely curtailing all production.

A brochure discussing the type of Ipsen equipment used by Fuller is available. Ask for your copy.

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 S. MAIN STREET • ROCKFORD, ILLINOIS

Metal Powders . . .

tracers use aluminum and magnesium powders because of the intense light given in their flames. Delays and fuses require zirconium, zirconium-nickel, boron or titanium, because these metals lend themselves well to controlled rates of combustion. Silicon and zirconium hydride are used in ignitors. Much of the knowledge of flammability developed over years of experimentation in ordnance materials can be adapted to rocket operations.

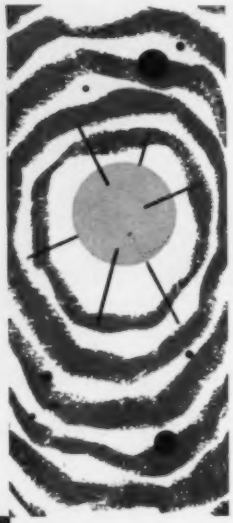
Metal powders such as boron, aluminum, magnesium and zirconium will play an important role in missile and rocket fuels. The chief difficulties to be overcome are residues left by combustion and technical problems in producing powders of precisely controlled size and surface condition.

A.G.G.

CHOOSE THE PIONEER

in production chilling equipment for stabilization of alloy steels and tools . . .

For 20 years we have been building low temperature testing and storage units. As the most experienced manufacturer in the field today, we take pride in our record for 100% reliability . . . and for building a little more into every unit produced.



Production chilling of stabilizing shafts utilizes this Cincinnati Sub-Zero unit, with temperature range of -70 to -150°. Chills 150 lbs. of steel hourly . . . 4000 BTU/hr at -120°F.

Write today for full-line catalog. Or describe your requirements so our Engineering Department can submit recommendations.

Member: Environmental Equipment Institute

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Silver-Indium-Cadmium Alloys for PWR Control Rods

Digest of "Metallurgical Design and Properties of Silver-Indium-Cadmium Alloys for PWR Control Rods", by I. Cohen, E. F. Losco and J. D. Eichenberg. Paper presented at Third Nuclear Engineering and Science Conference, Chicago, March, 1958, 27 p.

CONTROL RODS in nonmilitary nuclear reactors such as PWR must be:

1. Metallurgically stable under radiation and free from radiation damage interfering with proper functioning.
2. Sufficiently corrosion resistant to permit operation of unclad material in direct contact with pressurized high-temperature water.
3. Free from distortion under nonuniform temperature conditions.
4. Mechanically strong and ductile to withstand scramming loads.
5. Strong neutron absorbers having minimum absorption loss on long time radiation exposure.
6. Low in cost, easily fabricated, and of nonstrategic materials.

Silver-cadmium alloys have many desirable control material characteristics and were considered for pressurized water reactor use as early as 1950. They do not adequately meet requirements No. 2 and 6, however, so hafnium has been used for PWR control. Silver-cadmium alloys form a nonprotective oxide film and lose weight in 600° F. static water. Corrosion rate is considerably higher in oxygenated water than in degassed or hydrogenated water. The initial neutron absorption of silver-cadmium alloys is somewhat less than desired and loss of absorption is rather rapid under neutron irradiation.

The Westinghouse Bettis plant sought to design a silver-base alloy to meet control rod requirements by appraising the properties of known silver-base alloys and combining these with extension of basic physical and metallurgical concepts. For corrosion resistance, for example, the results of earlier work on improved resistance to air and chemical attack by adding aluminum, beryllium, and indium to silver were applied to a pressurized water environment. Sev-

DIG INTO YOUR GREASE!

. . . you'll find you get greater MoS_2 coverage per dollar and a more uniform blend by adding Acheson dag® 208

Unless you look carefully, you may find it difficult to distinguish between greases made with different molybdenum disulfide additives. They may appear alike . . . even feel the same . . . but that's where the similarity stops. By actual photomicrographic comparison, the finer particles in 'dag' Dispersion 208 are your assurance of greater coverage . . . at no increase in solids content. Or, looking at it another way, equal coverage and greater effectiveness can be obtained at a much lower solids content, thus extending the range of application to even closer-tolerance mechanisms.

Because of the ease with which 'dag' 208 can be handled, measured and blended, there are additional savings in compounding time and labor. This stable dispersion assures the blender and the end-user of a consistently uniform grease.

Acheson Colloids Company
Dept. MP-79, Port Huron, Michigan

Please send me free of charge your trial sample of

'dag' 208 ☐ 'dag' 200 ☐

NAME _____ TITLE _____

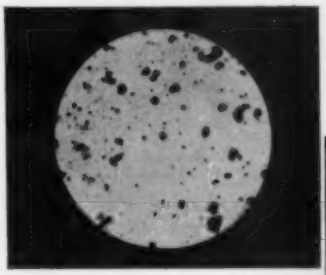
COMPANY _____

ADDRESS _____

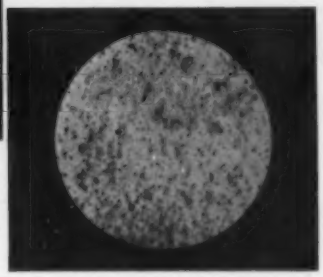
CITY _____ STATE _____

If you are one of the many progressive *marketers* now considering adding a moly-fortified grease to your line, we urge you to evaluate 'dag' 208 today! If you are one of the many current *users* of moly-fortified lubricants, be sure to specify that the ones you purchase are formulated with Acheson's moly dispersions. Send in the coupon for a complimentary sample.

The same advantages of molybdenum disulfide can be incorporated in petroleum oils and polyalkylene glycol fluids. 'dag' Dispersions 200 and 207 are the finest colloidal concentrates available for these applications. Experimental samples may be obtained upon request.



Shown here is a dramatic comparison of particle sizes. Both Acheson's new dispersion, 'dag' 208, (below) and the finest commercially available molybdenum disulfide powder (at left), have been magnified 300 times.



Tests prove that the predominantly finer particles in 'dag' 208 (at right) provide 80% greater hiding power . . . more coverage per dollar.

'dag' is a trademark registered in the U. S. Patent Office by Acheson Industries, Inc.

ACHESON *Colloids Company*
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For almost every hardness testing requirement

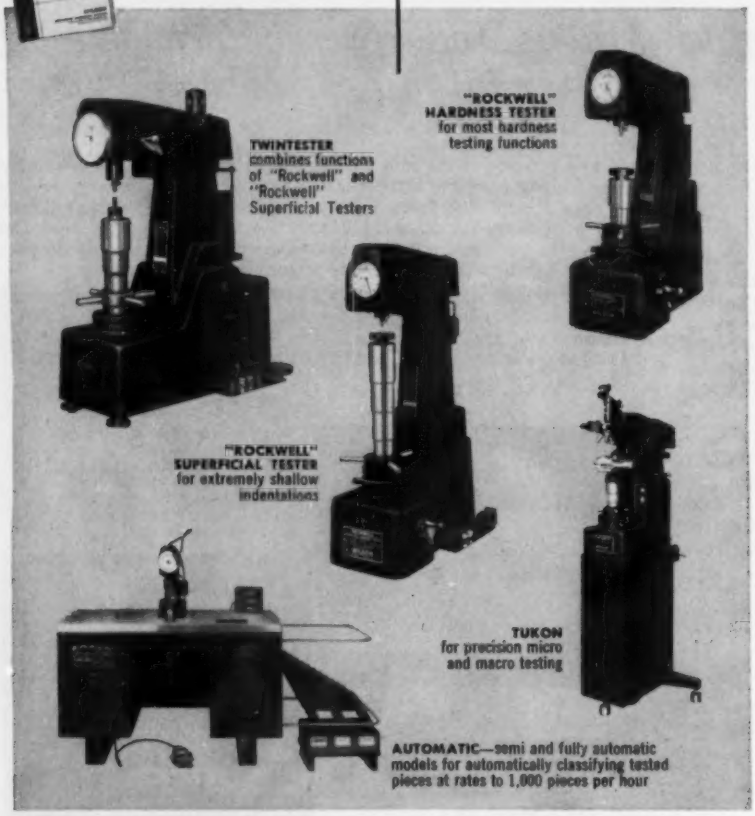
There's a Wilson "Rockwell" instrument to do the job

Wilson "Rockwell" Hardness Testers can help make your products better, stronger, longer lasting. They give reliable results on the production line, in laboratories, in tool rooms, and in inspection departments. They're as easy to use as a center punch, as durable as a machine tool, as sensitive and accurate as a precision balance. That's why Wilson "Rockwell" is recognized as the world's standard of hardness testing accuracy.

Write for Catalog RT-58. It gives complete details on the full line of Wilson hardness testing equipment.

Wilson "Brale" Diamond Penetrators give Perfect Readings

A perfect diamond penetrator is essential to accurate testing. Only flawless diamonds are used with Wilson "Brale" penetrators. Each diamond is cut to an exact shape. Microscopic inspection and a comparator check of each diamond—one by one—assure you of accurate hardness testing every time.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combines functions of "Rockwell" and "Rockwell" Superficial Testers
"ROCKWELL" HARDNESS TESTER
for most hardness testing functions
"ROCKWELL" SUPERFICIAL TESTER
for extremely shallow indentations
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for precision micro and macro testing
AUTOMATIC—semi and fully automatic models for automatically classifying tested pieces at rates to 1,000 pieces per hour

WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division
American Chain & Cable Company, Inc.
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ACCO

Si-In-Cd Alloys . . .

eral possible alloying elements and combinations of them were considered for realization of high neutron absorption. Maximum metallurgical and radiation stability require a single-phase alloy which remains single-phase during its lifetime in the reactor. Possible alloys were limited to an electron-to-atom ratio of 1.4. The expected transmutation of alloy constituents and the probable effect on properties were calculated.

Tentative alloy compositions were based on these calculations. These alloys were fabricated and experimentally evaluated. Indium was found to be particularly effective in imparting prolonged corrosion resistance in high-temperature water. The concentration of indium required for adequate neutron absorption was too high to ensure metallurgical and radiation stability. Replacement of some indium with cadmium gave a single-phase f.c.c. alloy (15% In, 5% Cd) which met all requirements for PWR control rods. Tests have confirmed the radiation stability and indicate only a small reduction in neutron absorption over the design life. Small amounts of tin from transmutation of indium improve corrosion resistance and mechanical strength. Full-size control rods have been fabricated and melting, forging, extrusion, and machining are easily performed. These rods will replace hafnium control rods in future PWR cores.

C. O. SMITH

Safe Handling of Beryllium

Digest of "Some Notes on Safe Handling Practices for Beryllium", by Webster Hodge, Battelle Memorial Institute, DMIC Memorandum 2, Sept. 22, 1958.

BERYLLIUM AND ITS COMPOUNDS are highly toxic. Though the A.E.C. recommendations for handling beryllium are well known, many contractors are puzzled about the practical steps necessary to stay within the limits of air contamination recommended by the A.E.C.

To begin with, the A.E.C. recommendations (issued in 1951 and still

PHOTO BY SARONI OF DYSSEN

"To achieve best design results—we must have steel of consistent quality"

—J. W. HUBLER, vice president engineering, Macomber Incorporated, Canton, Ohio.

"Engineers of construction products rely heavily on sources of material supply"—says J. W. Hubler, vice president of engineering at Macomber, one of the nation's foremost manufacturers of steel joists, roof decking, and structural steel framing.

"Because the relation of strength to weight is vitally important in the construction business, we design to give the architect the strongest, lightest, easiest-to-use product possible. To do this we must be sure the steel is right—every inch of it. For steel of consistent analysis and quality, we can rely on *Sharon Steel Corporation, Sharon, Pa.*"

SHARONSTEEL **SHARON** *Quality* **STEEL**

HARDNESS CONVERSION CHART

For Every Shop That Does Hardness Testing

This latest and most nearly accurate Hardness Conversion Chart is a necessity wherever hardness testing is done. It has been compiled and produced by CLARK, makers of the internationally respected CLARK Hardness Tester for "Rockwell Testing." Printed on heavy stock convenient for wall mounting, the chart is offered free of charge to hardness tester users. Just attach this ad to your letterhead or write "Send wall chart." A copy will be mailed to you without charge or obligation.

P.S. If you would also like information on CLARK Standard and Superficial Hardness Testers, we'll be glad to send that along too.

CLARK

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IN THE VACUUM MELTING FIELD . . .

LET'S MAKE NO MISTAKE ABOUT IT . . .

QUALITY — the manufacturing or fabrication of vacuum furnaces, vacuum crucibles and ingot molds are **not ordinary metal working jobs.** Quality depends on . . . .

EXPERIENCE — a good product in the vacuum melting field depends on 'know-how' gained through years of experience. Our quality gained by experience gives us . . . .

VERSATILITY — to quote on **furnaces, crucibles and ingot molds** of any design, plus an engineering department able to help in planning.

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Quality — Experience — Versatility
Call, Troy — ARsenal 3-3912

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TROY (GREEN ISLAND) N. Y.

Beryllium . . .

unchanged) are as follows:

1. The in-plant atmospheric concentration of beryllium should not exceed 2 micrograms per cu.m. as an average concentration throughout an 8-hr. day.
2. No personnel should be exposed to a concentration greater than 25 μg. per cu.m. for any period of time, however short.
3. In the plant neighborhood, the average monthly concentration at the breathing zone level should not exceed 0.01 μg per cu.m.

The American Industrial Hygiene Association adds: "Atmospheric concentration immediately hazardous to life: 50 μg per cu.m. for 6-hr. daily exposure."

Air Sampling

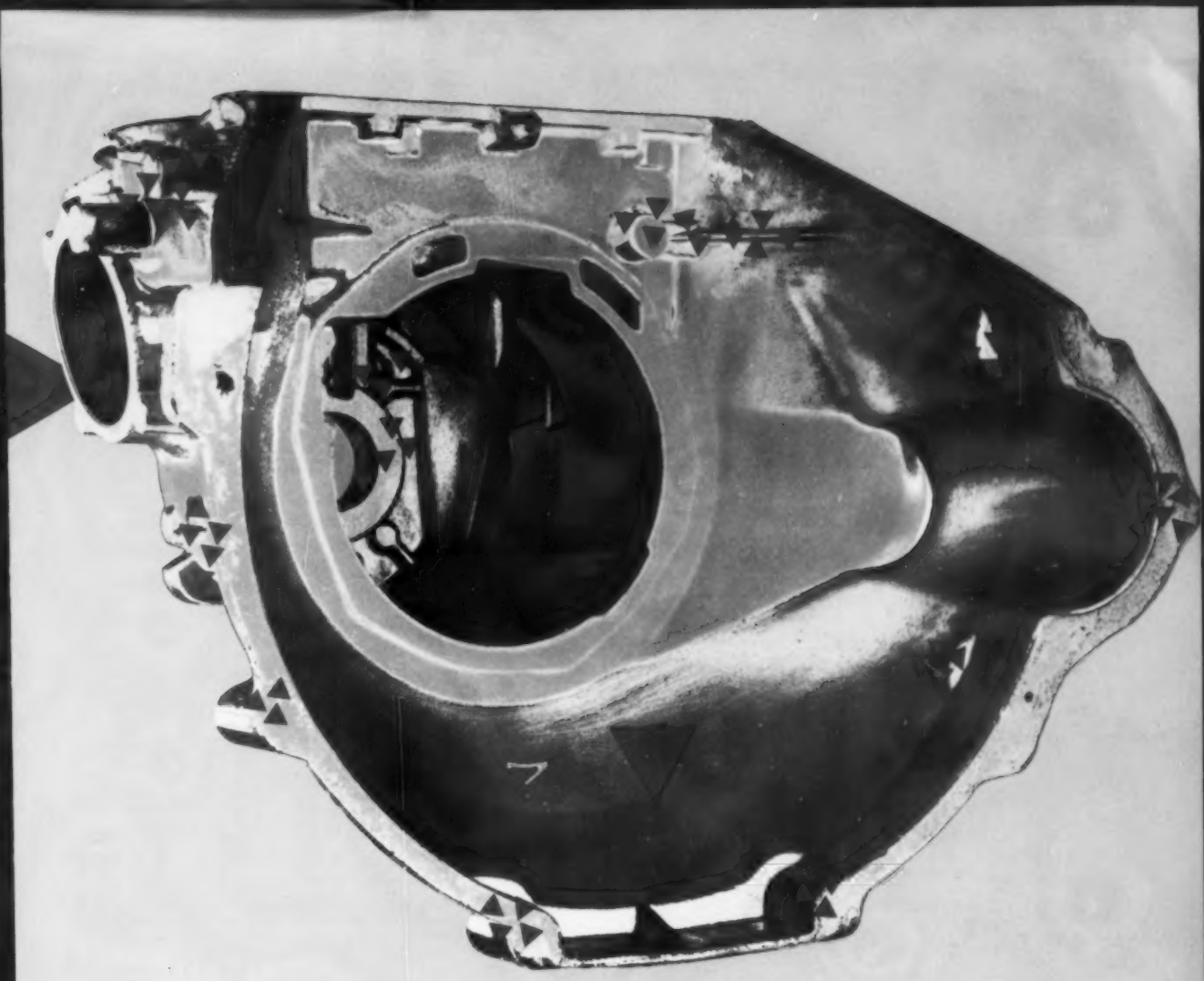
Commercial samplers are similar to a small vacuum cleaner. Instead of a bag, samples are collected on filter papers (Whatman No. 44 for 15 to 30-min. spot samples in the breathing zone around each machine and for general air sampling in the plant; Type S filters for 72-hr. outdoor samples). Laboratories throughout the country use various sampling arrangements modeled along these lines. All include pumping systems which pull a specified air volume through filter paper. Standard analysis technique then determines the amount of beryllium present.

Hygienic Programs

Medical programs stress pre-employment and periodic examinations of employees who work in areas where beryllium is processed. Chest X-rays are made regularly.

The change room is important. Employees are generally furnished with a complete change of clean clothes and shoes daily. Clothes are washed in a plant laundry every day and shoes go through a shoe-cleaning machine. Respirators, if used, go into a special washing machine and are sealed in plastic bags. Employees go through one-way gates from the change room to the plant. Once in, the only way back to the change room is through a shower room in which the water is turned on automatically as soon as a man steps inside. Thus, all men get a manda-

(*Continued on p.* 147A)



in castings...

Alcoa puts the metal where you want it

The design areas in this permanent-mold casting are pegged in red. The part itself is an automatic transmission housing for the '59 Ford car. It weighs 24 lb, 61 lb less than its cast-iron predecessor. The cyclone forces that whirl through modern automatic transmissions bring stress ranges in some parts of the casting up to 21,000 psi. The problem was to provide adequate strength without unnecessary weight in the casting walls.

Alcoa was not only able to offer a complete test facility, but was able to offer some sound design tips, too. Stresscoat and strain gage tests revealed the areas where special design attention was necessary. We were able to produce the parts to meet the exacting production schedule of the automotive industry.

In castings as well as forgings, screw machine parts, extrusions and impacts, Alcoa puts the metal where you want it. To you, this may mean fewer rejects, or it could provide the key to ingenious solutions for difficult design problems. Start now; write for Alcoa's Up-To-Dater, a starter file of ideas and design tips on Alcoa Engineered Products. Aluminum Company of America, 917 Alcoa Building, Pittsburgh 19, Pennsylvania.

ALCOA ALUMINUM

Alcoa puts the metal where you want it—in castings, forgings, impacts, extrusions and machined parts.

For Exciting Drama Watch "Alcoa Theatre," Alternate Mondays, NBC-TV, and "Alcoa Presents," Every Tuesday, ABC-TV

"STRESS AREAS"

News about COATINGS FOR METALS

from Metal & Thermit Corporation

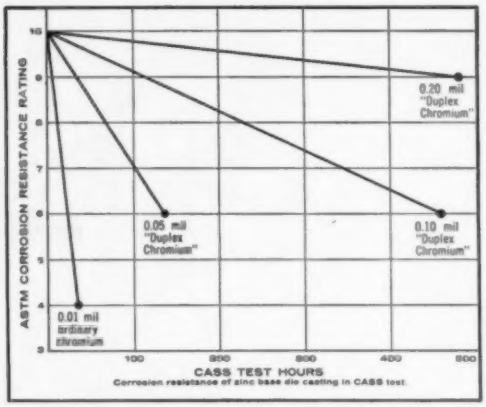
How to get the optimum protection of bright chromium plating

There are three requisites to increasing corrosion protection from chromium plating. (1) The deposit must be sufficiently thick. (2) There should be a crack-free chromium base topped by a special, finely cracked chromium deposit. (3) The plate should be more uniformly distributed over the part, so that recessed areas, too, are assured at least 0.03 mils minimum chromium thickness.

All of these requirements are easily met through UNICHROME SRHS® CHROMIUM plating processes. Work done for the automotive industry, long plagued by corrosion of brightwork in outdoors exposure, provides a good case in point.

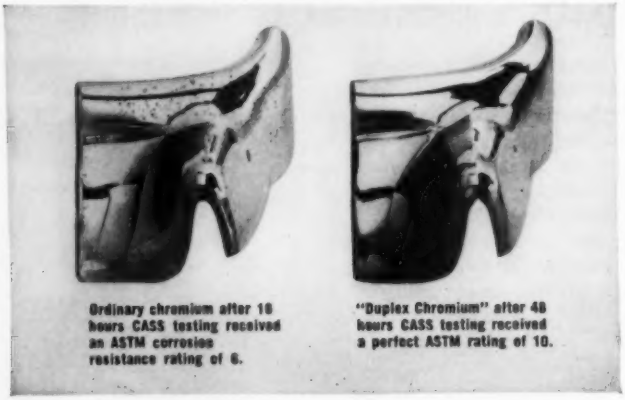
AN ANSWER TO OUTDOOR CORROSION

Note the results in the chart at right. In all cases, the thickness of undercoats was kept constant. Only the chromium plate was varied... from ordinary to "Duplex", and progressively thicker. M&T "Duplex Chromium" calls for first using Unichrome Crack-Free Chromium and its ability to throw into recesses and give a more uniform and fracture-free plate. This is followed by another deposit of Unichrome SRHS Chromium, with its *controlled* cracking. With increasing thickness, the protection increased tremendously. Durability as determined by rigorous, accelerated corrosion testing techniques was multiplied as much as *20 times*.



Zinc die cast specimens, all plated with 0.75 mil copper and 0.75 mil nickel prior to chromium lasted as shown above in the severe CASS test (Copper accelerated acetic acid salt spray). Ordinary chromium fared poorly. Optimum protection was approached by using Crack-Free Chromium and increasing the deposit thickness.

Steel bumper sections, showing difference in protection between ordinary chromium and Unichrome "Duplex Chromium."



Ordinary chromium after 16 hours CASS testing received an ASTM corrosion resistance rating of 6.

"Duplex Chromium" after 48 hours CASS testing received a perfect ASTM rating of 10.

WIDELY USEFUL FINISH

While the above case concerns itself specifically with an automotive problem, it indicates what thicker chromium in general, and crack-free chromium in particular can do for other design problems involving corrosion and wear. This plate blocks infiltration of corrosives to underlying metal.

Technical Papers giving full details on the advantages of thicker chromium deposits are available for the asking. Write METAL & THERMIT CORPORATION, Rahway, New Jersey.

METAL & THERMIT CORPORATION

12 B&W IFB lined single stack annealing covers in use in the strip annealing department of Weirton Steel Company, a division of National Steel Corporation, at Weirton, West Virginia.

uses lightweight B&W Insulating Firebrick for single stack annealing covers.

These 12 covers, lined with B&W K-20 Insulating Firebrick, have been in service more than two years in the annealing of low and high carbon strip from Weirton's 54" strip mill. Identical in construction, the covers are over 17 feet from base to skew and over 10 feet in diameter. The domes are of 9" K-20 IFB construction.

The K-20 is one of B&W's *lightweight* Insulating Firebrick. In fact, B&W K-20 IFB are at least a third of a pound lighter than other 2000 F insulating firebrick. This means savings in the overall weight of portable covers. Additional savings in fuel consumption and cycle time are possible because lightweight B&W IFB store and conduct less heat. Heat is kept in the furnace, not in the lining.

This application points out advantages of light weight in insulating firebrick constructions. And B&W makes the *lightest* weight insulating firebrick. Consult your B&W Refractories Representative for information on how you can profit with lightweight B&W IFB.

Bulletin R-2-H available on request.

B&W REFRACTORIES PRODUCTS:
B&W Allmul Firebrick • B&W 80 Firebrick • B&W Junior Firebrick • B&W Insulating Firebrick • B&W Refractory Castables, Plastics and Mortars • B&W Silicon Carbide • B&W Ramming Mixes • B&W Kaowool

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WORKS: AUGUSTA, GA.

R-617

tory shower. A lunch area is inside the general working area. Disposable containers are required and must be discarded after use.

Good housekeeping is essential. Push brooms, compressed air, or high-pressure water hoses must not be used. An industrial vacuum cleaner is prefereable for dry areas. If a portable cleaner is selected, the exhaust should be connected to the ventilation system. Mops or squeegees are satisfactory in wet areas and all mop water is carefully washed down the drain. Surface swipe tests keep the amount of loose beryllium dust below 25 μg. per sq. ft. They are made by swabbing about 1 sq.ft. with a 15 cm. Whatman No. 41 filter paper. One company, General Electric, says: "Beryllium will not be handled with the bare hands".

All equipment should be provided with a ventilating hood to gather chips and dust. Also, the shop should be under a slight negative pressure to prevent escape of dust into noncontaminated areas.

The hood design must be determined by air sampling at the breathing zone. A drill press usually needs only a flexible hose attached to the air exhaust system, while a lathe or a milling machine may require a complete enclosure. The air intake should be near the source of dust or fumes. Also, to obtain high velocities, the openings to the work area should be kept to a minimum in size and number.

Collection Systems

Different systems are used at different companies. At Speed Ring Experimental & Tool Co., 6-in. diameter ducts lead to 4-in. diameter headers. Branches from these extend close to each machine. When a machine is used, a flexible metal hose is attached to the branch and brought close to the tool. All ducts discharge to a bag house with a filter.

At Los Alamos Scientific Laboratory, the ventilation system is quite elaborate. Lathes, milling machines, grinder and drills are totally enclosed by lucite hoods which are exhausted through metal pipes and flexible hose to an equipment room above. Here the contaminated air passes through a precipitator and a bag collector.

Welding operations at the University of California Radiation Laboratory are carried on in a totally enclosed glove box made of plywood painted white and provided with a lucite window. A wet collection system is used as a prefilter.

Waste Disposal

Various methods of waste disposal are used. Coarse chips and mixed wastes can sometimes be returned to the prime beryllium producers for remelting. Where no ocean is convenient and local regulations prevent fines and other wastes being washed down the drain, they can be placed in sealed cans and buried in the ground.

Responsible and inventive foremen should be in charge of all repair work. It must be remembered that one man with a welding torch can contaminate an entire working

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Sunbeam will handle the entire job of designing, building and installing your next furnace equipment. And whether you need an entire furnace line . . . or a single piece of equipment . . . *it's wise to get a quote from SUNBEAM.*

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Polimet

A NEW NAME IN METALLOGRAPHIC POLISHERS

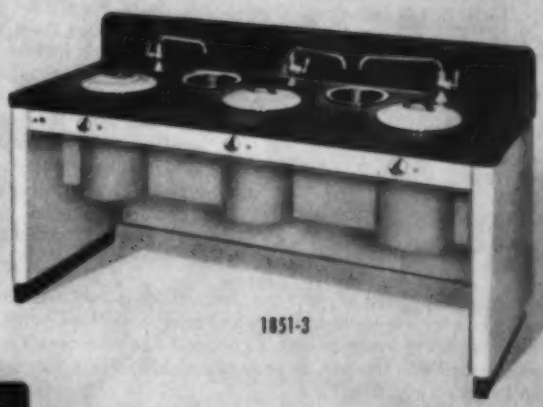
- VARIABLE SPEED—100-1200 r.p.m.
- QUIET OPERATION
- VIBRATION FREE
- EASY CONTROL
- HIGH TORQUE—½ h.p.
- AVAILABLE IN 1, 2 or 3 UNIT TABLES
- INTERCHANGEABLE BALANCED WHEELS
- VITREOUS FINISHED, EASY TO CLEAN BOWL

With infinitely variable speed over a wide range it is possible for the operator to select the exact speed desired for the particular sample at hand. The complete speed range is controlled by turning a knob. No cranking is required to change speed, no belts, pulleys or mechanical clutches are used, eliminating the source of most vibration present in other variable speed polishers. The electronic control is accomplished through the use of only one vacuum tube and the complete electronic circuit is mounted on a 4" x 4" panel easily accessible on the outside of the motor.

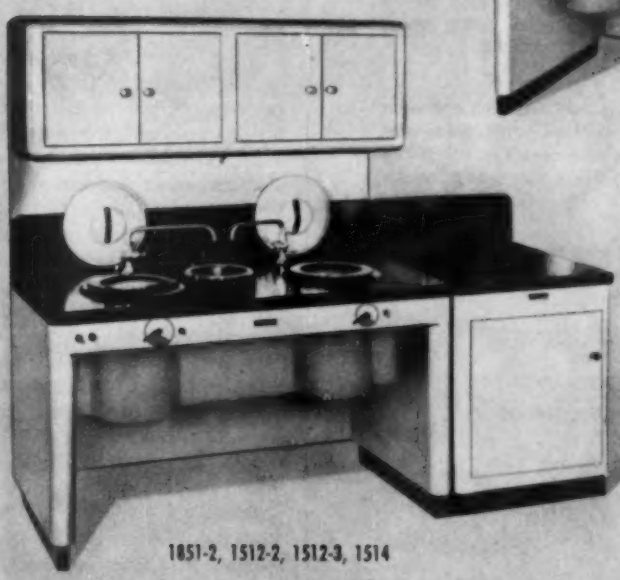
The 1851 Polimet series is furnished in the Buehler steel polishing tables, finished in silver gray hammertone. The top and edges of the table are black formica. One, two, or three unit tables are available.

1851-1

1851-2



1851-3



1851-2, 1512-2, 1512-3, 1514

Buehler Ltd.

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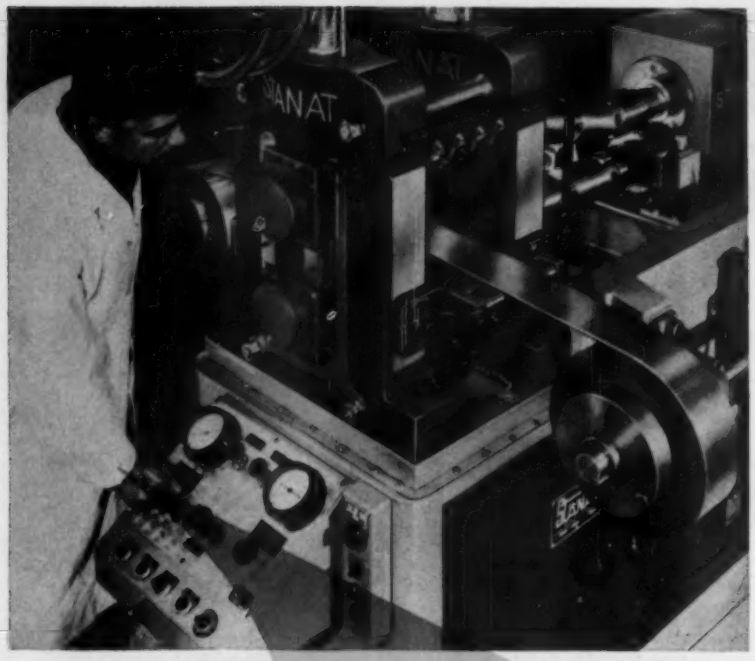

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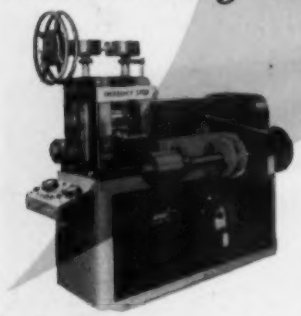

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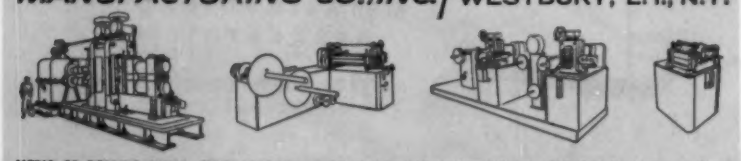

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Beryllium . . .

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A handbook due to be issued by the University of Cincinnati is expected to provide authoritative guidance to the safe handling of beryllium. Meanwhile, contractors, subcontractors and other suppliers to the armed services who need help in dealing with beryllium hazards may communicate with Headquarters, Air Materiel Command, Wright-Patterson Air Force Base, Ohio, Attention MCD.

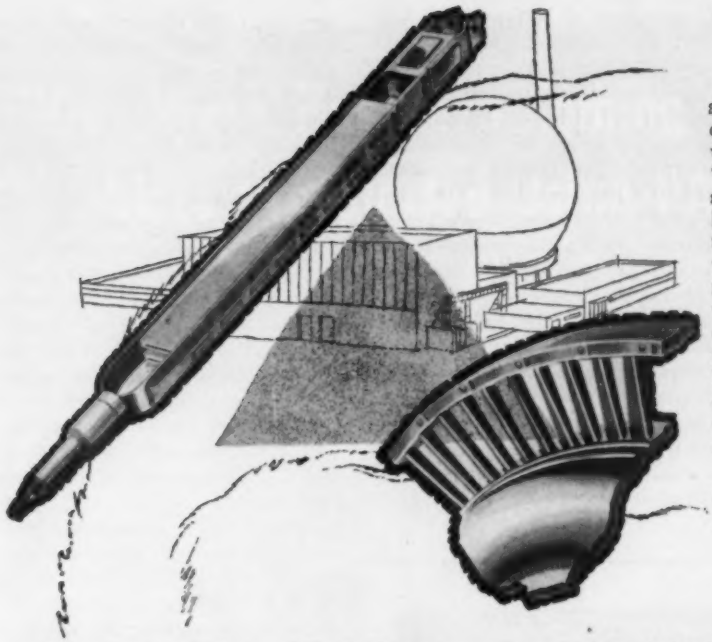
C.R.W.

Stress-Corrosion Cracking

Digest of "Hydrogen Absorption, Embrittlement and Fracture of Steel," by A. E. Schuetz and W. D. Robertson, *Corrosion*, Vol. 13, July 1957, p. 33-54.

THIS PAPER gives the results of a four-year research project on sulphide stress-corrosion cracking observed in alloy steels. The interest in the problem was stimulated by the failure of alloy tubing in several sour gas condensate wells. The complex nature of the problem is clearly indicated by earlier investigations (see "Symposium on Sulphide Stress Corrosion", *Corrosion*, Vol. 8, 1952, p. 326-360) which were unable to reach agreement on the mechanism of failure.

The purpose was to explain the pronounced decrease in fracture stress of steel submerged in hydrogen sulphide, and to distinguish between two possible proposed mechanisms of failure: (*a*) fracture due to absorption of hydrogen and (*b*) fracture due to stress-corrosion. To separate the numerous variables, a simple system of relatively pure Fe-Ni alloys was chosen with compositions varying from 0 up to 30% Ni. By various heat treatments, fractures in different structures (such as austenitic, martensitic and ferritic



Today's metallurgical engineers and scientists are constantly meeting the challenge of sweeping technological advances. Electronic brains that solve "impossible" problems . . . jets and space craft which open brand-new horizons . . . reactors that produce fantastic amounts of nuclear energy. Advances such as these *demand* better metals . . . metals free of inclusions, with better electrical conductivity, increased hot strength, extended creep resistance and fatigue limits. In turn, better refractories are a "must" in order to precisely control purity and composition during the development of these metals.

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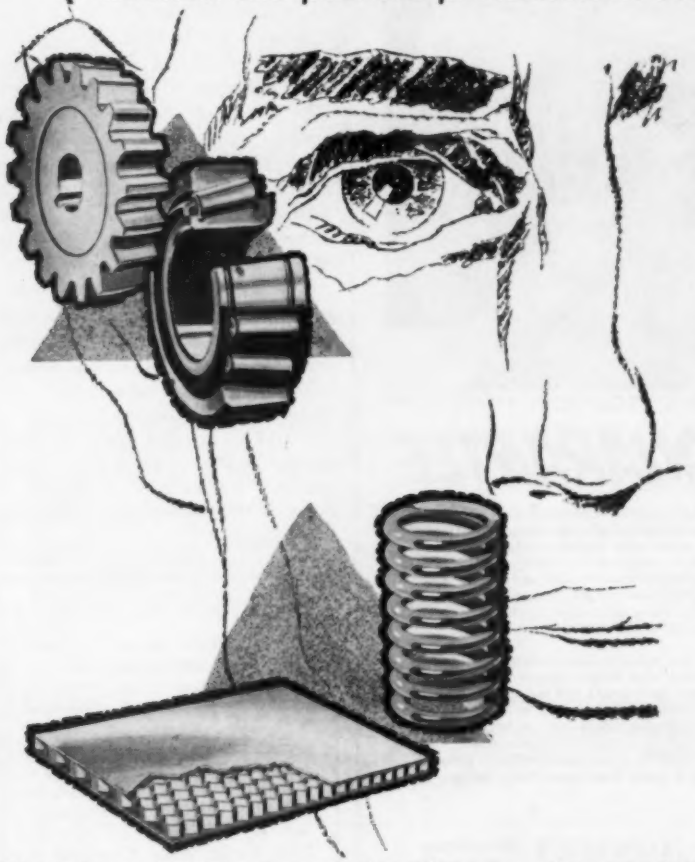

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Stress-Corrosion . . .

of the same alloy composition) could be investigated. The influence of small amounts of impurities (copper, manganese, silicon) was also studied. In some of the tests, the samples were merely submerged in hydrogen sulphide, whereas in others hydrogen was introduced into the samples by cathodic charging with various current densities. All tests were run at room temperature. As a result of this work, it seems established that failure of those steels in sulphide environments is caused by the absorption of hydrogen.

The investigation followed essentially four different lines: First, the phenomenon of embrittlement was studied in various annealed and cold rolled 1/16-in. sheet specimens by immersing in a saturated aqueous solution of hydrogen sulphide for periods up to 140 hr. Immediately afterwards, the samples were bent around a ½-in. mandrel. The number of 180° reverse bends before fracture gave a surprisingly reproducible measure of embrittlement. The results are consistent with the assumption that the embrittlement is due to a diffusion process; aging experiments at various temperatures showed that the embrittlement disappears to a large extent. A suppression of the yield point in tension was also caused by presence of hydrogen. Furthermore, U-shaped specimens with superimposed elastic stress were tested in hydrogen sulphide, and the time to fracture measured. The results indicate that fracture was not caused by corrosion cracking since (*a*) microstructural observations did not show any preferred corrosion path of the crack, (*b*) failure in the 30% Ni alloy (which has a low hydrogen solubility) occurred only when the hydrogen content was raised by cathodic charging and (*c*) failure occurred during cathodic charging in acid and alkaline solutions where no structural corrosion was observed.

The second part of the investigation was concerned with Fe-Ni alloys. The absorption of hydrogen from aqueous solutions (at room temperature and atmospheric pressure) was studied. One has, however, to keep in mind that, due to the voltage difference between the steel and the solution, the "effective hydrogen pressure" (fugacity) is about 10^6 to 10^8 atmospheres. The results of immersion in hydrogen sulphide show that in Armco ferrite no saturation could be reached (probably due to blistering) whereas addition of 0.3% C gave saturation with hydrogen at about 7 ml. per 100 g. With increasing nitrogen content, decreasing saturation values were obtained from 5 ml. per 100 g. at 5% Ni to 0.5 ml. per 100 g. at 30% Ni. The saturation value was independent of the structure (ferritic, austenitic or martensitic).

The diffusion coefficient of hydrogen was determined from the time interval needed to reach saturation and also from an independent measurement of the permeation rate. The value ranges between $D = 2 \times 10^{-7}$ sq.cm. per sec. for Armco ferrite and $D = 15 \times 10^{-7}$ sq.cm. per sec. for 30% Ni alloy, but it depends also on the way of charging

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Write for Bulletin CT-175 which has complete details on MARVEL High-Speed-Edge Hack Saw Blades.

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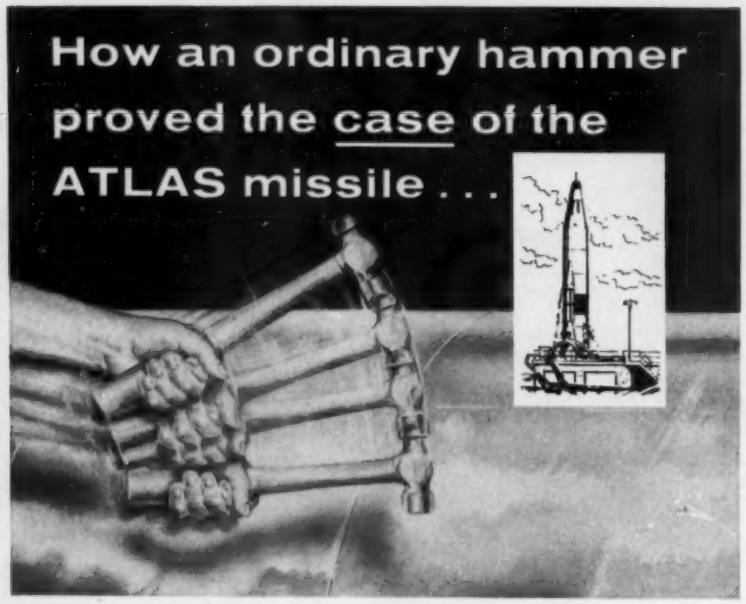
Stress-Corrosion . . .

with hydrogen. These room-temperature values are nearly two orders of magnitude smaller than values obtained by extrapolation from high-temperature data. However, they are consistent with recent reliable values determined by Hill.

In the last part of the investigation, delayed fracture was studied, but only in a 90 Fe, 10 Ni alloy. To obtain well-defined conditions, the wire specimens were saturated with hydrogen before applying the load, and kept under charging conditions during the test. The fracture stress for the ferritic structure is 275,000 psi. without hydrogen, whereas the material containing hydrogen fractured in a few hours at stresses of about 80,000 psi. However, there seems to exist endurance stress which decreases with increasing hydrogen content; no fracture was observed in the ferritic structure at stresses below 70,000 psi. for a hydrogen concentration of 9 ml. per 100 g. and at stresses below 30,000 psi. for a hydrogen content of 15 ml. per 100 g. In the martensitic structure, the fracture stress even decreased to 15,000 psi.

The variation in hydrogen content in the different samples was obtained by changing the current density during cathodic charging. The hydrogen content increased logarithmically with the current density. An increase in current would give additive protection against corrosion. However, the fracture stress decreased at higher current densities, and thus it is reasonable to conclude that fracture is not due to stress-corrosion but due to hydrogen embrittlement. Austenitic structures have not been investigated. Absence of their failure in previous tests may be due to the low solubility and diffusion rate of hydrogen. The present tests show that load-carrying capacity can be reduced up to 90% and that the final fracture stress depends on the hydrogen content. Hence any measure to prevent failure has either to reduce hydrogen or to select materials less susceptible to hydrogen embrittlement.

GUNTHER SCHOECK



The body of the missile, essentially one big fuel tank, is similar in principle to an inflated football. Convair-Astronautics broke new ground in missile design by developing a super-strong structure with a comparatively thin stainless steel skin to keep weight to a minimum. This stainless steel skin is so thin that the interior has to be pressurized to preserve the shape of the body as propellants are consumed in flight, or when the missile is being transported on the ground.

Some critics, however, thought the body was too fragile—"You could dent it with a hammer." So, recently, when the Scientific Advisory Board, engaged in a re-evaluation of all missile programs, arrived at Convair-Astronautics to take a reading on the ATLAS, they found that Convair had thoughtfully placed a number of hammers within easy reach of a finished missile. "Go ahead, bash it," invited Convair. The SAB members swung lustily. *Not a dent was registered*, for, although the walls are thin, the stainless has a minimum tensile strength of 200,000 psi.

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Creep-Rupture Acceptance Testing

Digest of "Combination Creep-Rupture Test Specimen", by M. J. Manjoine, *ASTM Bulletin*, No. 222, May 1957, p. 36-37.

THIS PAPER describes a test specimen which has proved worthwhile in acceptance testing and in the development of new alloys and heat treatments.

The proposed specimen consists of two sections, a smooth test section and a notched test section. The specimen dimensions can be varied to obtain different stresses in the notched and smooth sections. Different stress concentration factors can be obtained for the notched sections by changing the diameter of the test section and the radius of curvature at the root of the notch.

By using the proposed combination specimen, variables associated with specimen history and heat

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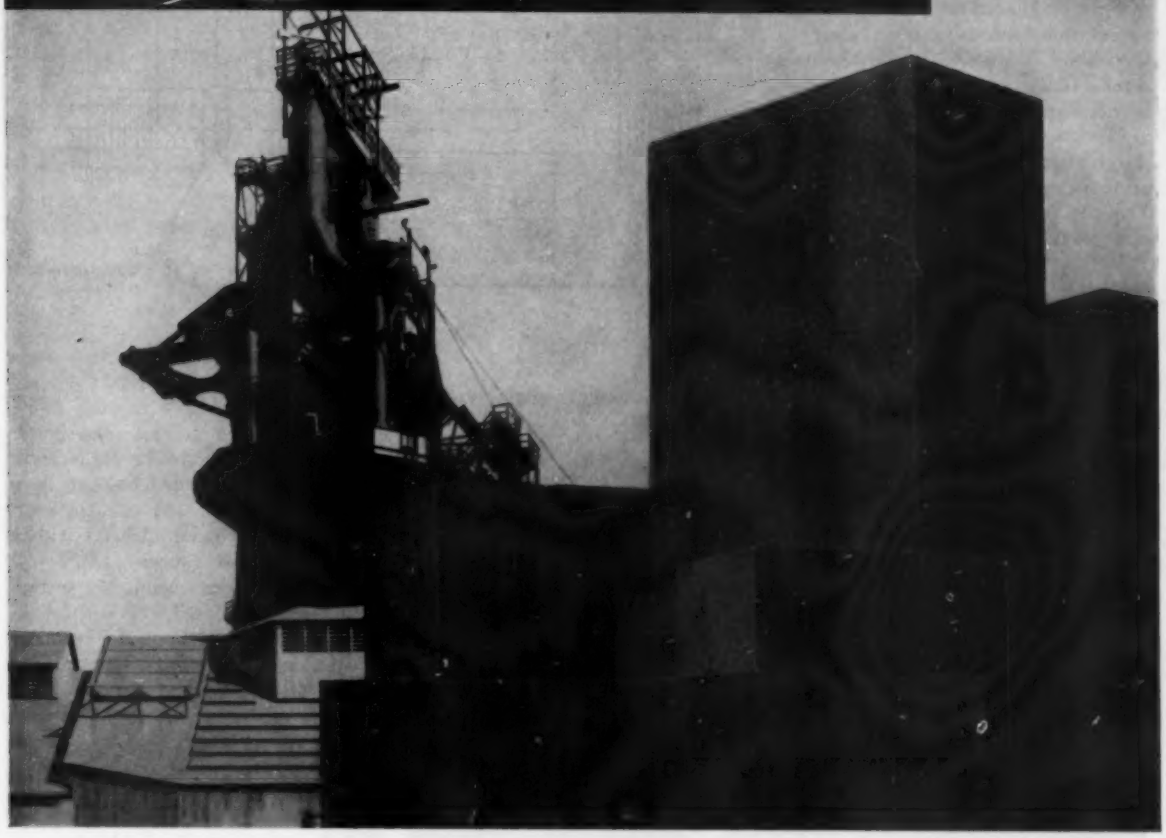

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Creep-Rupture Test . . .

treatment are eliminated. Since the smooth and notched sections are tested simultaneously, the testing time is reduced, for when either test section is broken, the other can be reloaded and the test continued.

Examples are given of the use of this specimen in the development of alloys and in acceptance testing. The data for notched and smooth bars of 15 heats of Discaloy with varying titanium content for a stress of 60,000 psi. at 1200° F. are plotted. Up to approximately 1.95% Ti, the smooth bars have the shorter rupture life, while for higher titanium contents the notched bars have the shorter life. By using a combination specimen, all heats with a titanium content below 1.95% will first fail in the smooth bar section and those above 1.95% will fail in the notched section. In both instances, the remaining unbroken portion of the test specimens would be reloaded and continued to failure. The testing time is thus reduced by a value approaching ½ for heats near 2.0% Ti. More important is the fact that the reliability of the data has been increased because both test sections have the same history.

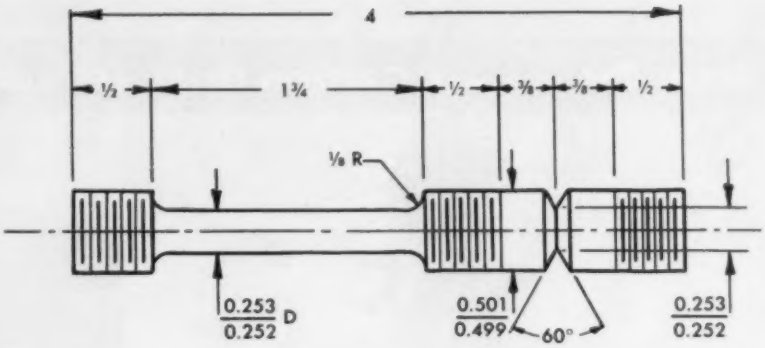

Diagram of Combination Creep-Rupture Test Specimen

To date, the most important application of this combination specimen has been in acceptance testing of heats or lots of material to be used for elevated-temperature service. If the criteria for acceptance testing are given in terms of (*a*) the minimum rupture life of a smooth bar, (*b*) the rupture ductility of the smooth bar, and (*c*) the minimum rupture life of a notched bar with a given stress concentration, a single test with the combination specimen will determine whether a given heat is acceptable.

Finally, the combination specimen can be used in the development of high-temperature alloys or heat treatments for these alloys. In this instance, it is generally desired to know whether a material is notch sensitive at the service temperature. The criteria then are that the material should have a minimum smooth bar rupture life and that the rupture

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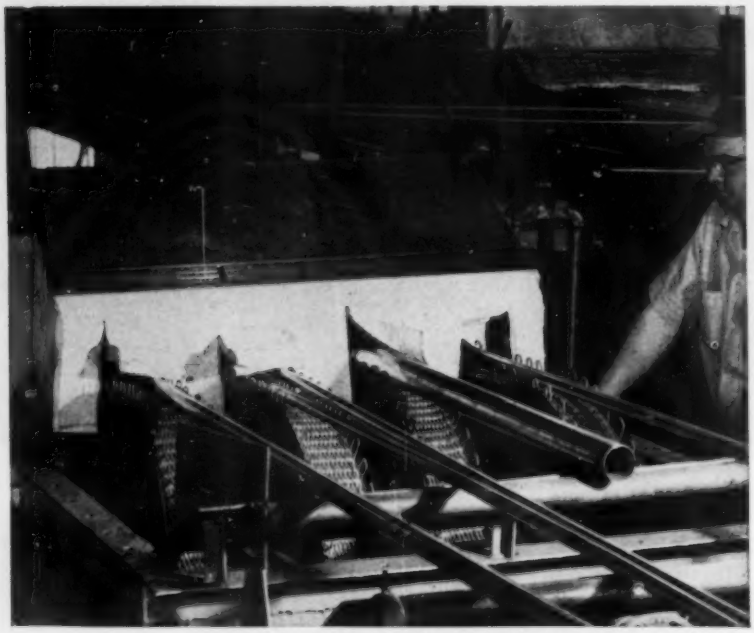

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Creep-Rupture Test . . .

life of the notched bar at the same stress and temperature must be greater than that of the smooth bar. In this instance, only a single test is required and no reloading is necessary.

HANS CONRAD

Oxidizing Test for Revealing Austenitic Grain

Digest of "New Oxidizing Method for Revealing Austenitic Grain", by Yunoshin Imai and Hiroshi Hirotani, *Science Reports of the Research Institutes*, Tohoku University, Sendai, Japan, Vol. 9, December 1957, p. 467-475.

A NEW OXIDIZING METHOD for revealing austenitic grain boundaries in steel has been developed using borax. Tested on some carbon steels and special alloy steels, the results compare favorably in excellence with those obtained by the carburizing method. Moreover, the new method appears to be somewhat superior to other methods in practical use because of its simple technique and reliability.

This paper proposes the use of an oxidizing etch of a polished surface, developed in molten borax at 1700° F. The polished steel test specimen is heated in a high vacuum to well above the austenitizing temperature for a suitable time (no more than 3 hr.). It is then oxidized by introducing air into the furnace for from 3 to 5 sec. and is immediately transferred to the molten borax at 1700 to 1725° F. in a graphite pot and stirred for 30 to 45 sec. to melt the thin oxide film. It is then quenched in water, to help remove the borax film and reveal a clean surface with prominent oxidized grain boundaries. After being washed and dried, the specimen can be examined microscopically with or without a slight repolishing.

It appears that the process offers a method of grain-size determination which does not involve the problem of carbon or nitrogen absorption, as when the specimen is carburized, and would be of special value in the more highly alloyed

steels. This process appears to take less time and works under more accurate conditions of temperature, and on steels difficult to carburize.

With additional research, this method could become an accurate and valuable means of indicating austenitic grain size on almost any steel at almost any temperature and time above the critical range. It would be of particular value in the stainless steel groups, especially the straight chromium types which are sensitive to excessive grain growth when overheated.

What is also needed is a sensitive method for indicating under a microscope the fine grain-boundary films of Type II iron sulphide which cause so much harm by reducing the ability of steel to be hot worked at high temperatures without intercrystalline cracking. This test may provide much needed answers; determing why high iron oxide in low-carbon high-sulphur steels will remove "hot shortness", and conversely why, after the complete deoxidation of this steel with aluminum, further additions of aluminum will cause the formation of Type II iron sulphides and high "hot shortness", high conditioning costs, fine grain, and abnormality.

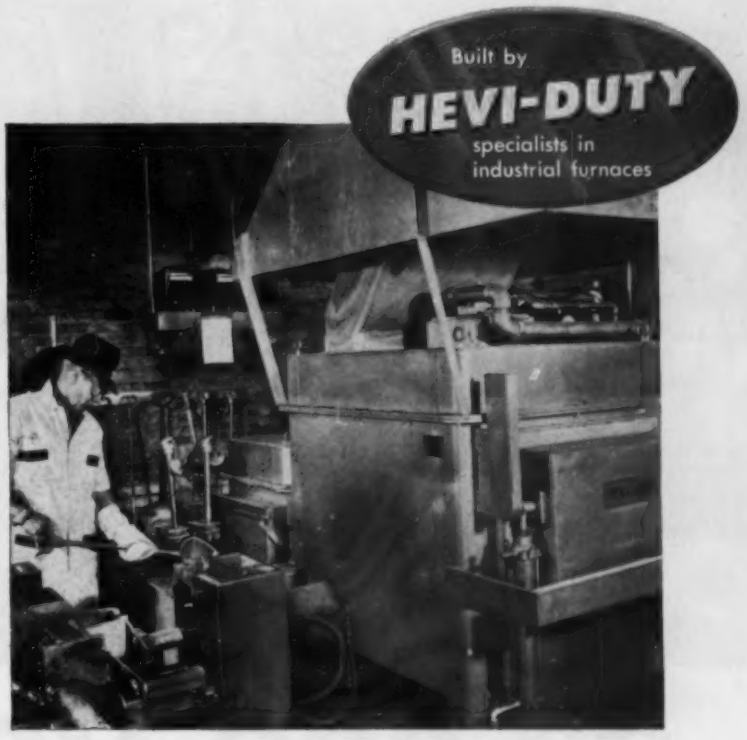
H. W. McQuaid

Thin *n*-Type Layers of Germanium

Digest of "Some Aspects of Alloying Onto Germanium Surfaces", by J. W. Peterson, J. McGlasson, Jr. and W. C. Hittinger, *Journal of Metals*, Vol. 9, Section II, July 1957, p. 823-827.

JUNCTION-TYPE TRANSISTORS require introduction of small amounts of impurity elements in alloyed regions of the semiconductor. Regions of *n*-type (excess electrons) alloys on single-crystal germanium (*i*-type or intrinsic semiconductor) must have uniform and controlled thickness between 0.00010 and 0.00014 in. over an area of at least 0.002 sq.in. with a concentration of about 10^{17} *n*-type atoms per cc. and no other foreign material while resistivity of the underlying germanium is unchanged.

Production of this uniform layer requires orientation of the crystal surface to the (111) plane within about 11'. (*Cont. on p.* 160)



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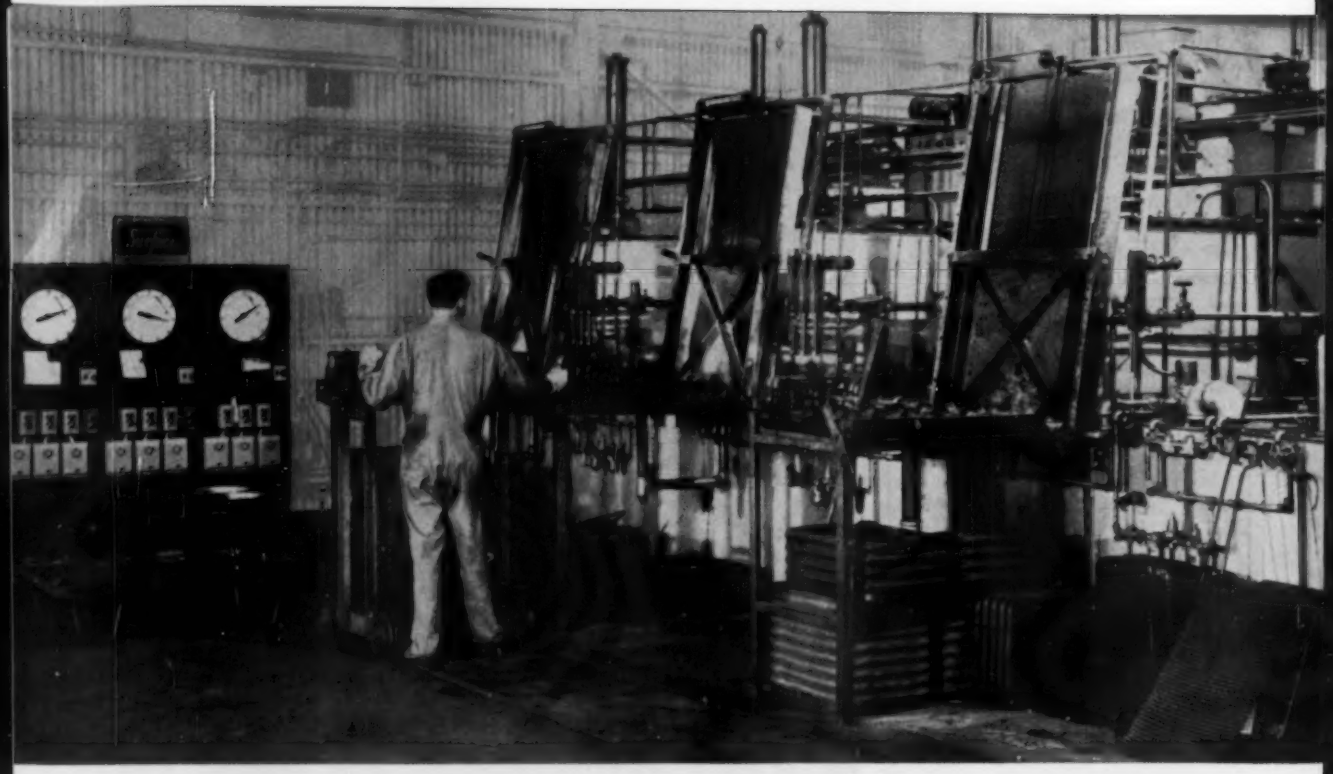

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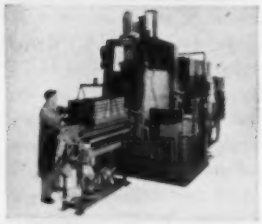
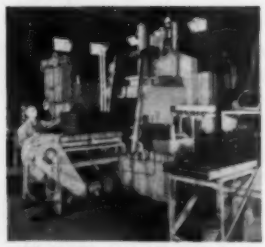
Baskets: 7,800 hours

This record is convincing evidence that Surface quality keeps maintenance cost (frequently a major portion of operating expenses) to an absolute minimum. Write for Allcase Bulletin SC-174.





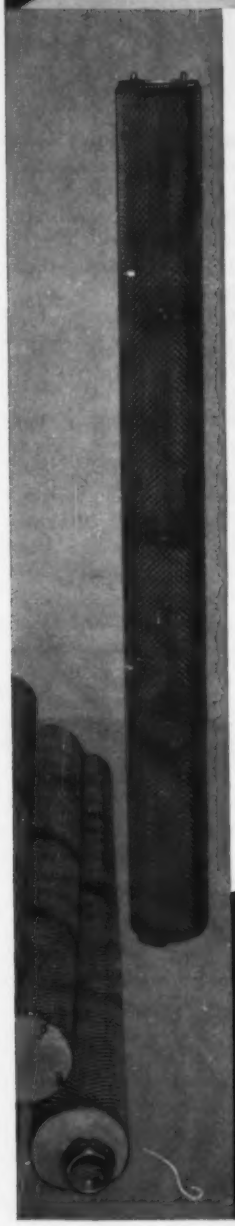
Illustrations shown are typical Allcase installations.

wherever heat is used in industry

SURFACE COMBUSTION CORPORATION

2377 Dorr St., Toledo 1, Ohio

In Toronto: Surface Industrial Furnaces, Ltd.



Who cares about your Wire Cloth Fabrications?

CAMBRIDGE does . . .

that's why you automatically get service with your order . . . whether you need dozens of midget strainers or a single giant-sized retaining screen.

Careful, competent workmanship and constant inspection assure you of quality . . . modern machinery and accurate scheduling assure you of prompt delivery. And, a Cambridge Field Engineer follows up your order to make sure our product is giving you the best possible service. Let us quote on your next order for wire cloth fabrications. We manufacture wire cloth from any metal or alloy—including titanium—in nine basic weaves. We'll work from your prints or draw up prints for your approval. Call your Cambridge Field Engineer . . . he's listed in the yellow pages under "Wire Cloth". Or, write for FREE 94-PAGE CATALOG.

The Cambridge Wire Cloth Co.

Department B • Cambridge 7, Md.

Manufacturers of Wire Cloth, Metal-Mesh Conveyor Belts, Wire Cloth Fabrications

PROGRESS REPORT

Fabricating Columbium Alloys

First, let's settle the question "When is columbium niobium?" It depends on whether you're a chemist or a metallurgist. And since we are interested mostly in metallurgy at the TAPCO Group, we call it *columbium*.

Columbium is growing more and more interesting to the people with product design problems involving high operating temperatures, greater stresses, and severe oxidizing conditions. In fact, it is rapidly overtaking molybdenum as the expert's choice for refractory structural materials.

Because of this increased interest in columbium, now available in sufficient quantities, the TAPCO Group has been conducting an extensive columbium development program during the past eighteen months. This program, a joint venture with E.I. duPont de Nemours & Co., Inc., has contributed much information about the properties of columbium and has produced better methods of working with it.

ABOUT WORKABILITY—At TAPCO, forging methods have been investigated with a variety of columbium extruded bars. Excellent progress is being made on jet engine parts and missile structural components. One method used to produce turbine blades includes heating blanks to forging temperature in an Argon-flooded furnace, then press-forging them in conjunction with a TAPCO-developed die lubricant. Simple surface-polishing is all that is needed to finish these precision-forged parts.

An important phase of the TAPCO program is the development of welding procedures for columbium alloys. TAPCO welding engineers have successfully joined columbium by spot and seam resistance methods, have also fusion-welded columbium sheets successfully.

WHAT DOES COLUMBIUM OFFER? If you design or build aircraft engines, missiles or supersonic airframes, you'll be interested in the research the TAPCO Group and duPont have done to improve columbium properties.

It has excellent strength and shock resistance at greatly elevated temperatures... up to 2600 F, even 3000 F with some alloy compositions.

Now, about columbium *vs.* molybdenum. Columbium is easier to fabricate than moly. And much, much more resistant to elevated-temperature oxidation. For example, a simple columbium alloy is as much as 100 times better than moly on oxidation resistance. And a complex columbium alloy may be as much as 500 times better.

At TAPCO, coating materials for columbium are being developed, including one that reduces the oxidation of columbium at 2200–2300 F to practically zero.

WHERE TO USE COLUMBIUM—Columbium blades for jet engine turbines are an actuality... we'll be glad to show you finished forgings. Columbium also makes sense for such other jet engine "hot zone" parts as vanes, turbine wheels, after-burner liners, nozzles and nozzle flaps, and burner holders.

The use of columbium sheet seems very promising for missile structural components, such as leading edges, hinges, brackets, and the "ribs" and "skin" for airframes.

We would welcome an opportunity to tell you more about TAPCO's columbium research, and to discuss with you the many exciting possibilities of this space-age metal.

TRW

TAPCO GROUP

Thompson Ramo Wooldridge Inc.

Dept. MP-759 • Cleveland 17, Ohio

Germanium . . .

Lead is used as a solvent because it is neither a *p*-type nor *n*-type impurity, can be highly purified and will readily wet germanium at a temperature well below that required for appreciable solution of germanium. Its low yield strength avoids serious straining of germanium during cooling and it is readily removed (chemically) after alloying.

Antimony is used as the *n*-type donor impurity because of relatively low vapor pressure and generally satisfactory behavior. A concentration of about 0.01% in specially purified lead produces the desired resistivity.

Germanium wafers and antimony-doped lead pellets are chemically cleaned and heated inside a resistance-type furnace in deoxidized and dried hydrogen to about 650° C. (1200° F.) before combining them inside the furnace.

On heating above the melting point of lead, germanium is dissolved. During subsequent cooling, its solubility decreases leading to crystallization of germanium and donor atoms from the melt. These crystallizing atoms rebuild the previously dissolved germanium structure to produce a regrowth layer containing the donor atoms. After completing the alloying cycle, lead is removed by selective chemical etching to reveal the top surface of the regrowth layer.

A heating period of 20 to 30 min. to 700° C. (1290° F.) is satisfactory since is provides good wetting during the initial portion and maintains a planar solid-liquid interface during solution of germanium. Steady-state conditions and uniform germanium concentration in the melt can be obtained in 5 to 10 min. at 700° C. (1290° F.).

The desired thin, uniform regrowth layers can be produced by either very rapid or very slow cooling, with slow cooling preferred. It is believed that improved flatness from very slow cooling results from reduction of temperature gradients (by using auxiliary heaters to reverse the usual temperature gradient) rather than from the closer approach to equilibrium.

C. O. SMITH

Metal Progress

Bulletin Board...

The Buyers Guide For Metals Engineers

LA-CO

Aluminum Soldering Flux

Now . . . Solder Aluminum with ordinary soft solders

- Use 60-40, 50-50, 40-60, 95-5 solders
- No new soldering techniques
- Non-acid . . . Self-cleaning

A major breakthrough in aluminum fabrication. Use ordinary soft solders . . . ordinary irons or torches. Remarkable fluxing action achieves perfect bond of aluminum and solder making possible the fabrication of aluminum to aluminum, copper, steel, stainless steel, galvanized iron, brass, etc.

Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND

LAKE Chemical Co.
3079 W. Carroll Ave.,
Chicago 12, Ill.

LA-CO

Silver Solder Flux

Greater speed and economy for all silver soldering!

- Packed in tins
- Will not harden
- Non-acid . . . Self-cleaning

For all silver soldering in 1125° to 1700° F. heat range. Dissolves all refractory and non-refractory oxides . . . solder penetrates completely into all areas, for maximum strength without solder waste. Completely acid-free—will not pit or stain metals. Always-ready paste form . . . will not harden or crystallize.

Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND

LAKE Chemical Co.
3079 W. Carroll Ave.,
Chicago 12, Ill.

LA-CO

Stainless Steel & Chrome Soldering Flux

Safer . . . Surer . . . Cleaner

- Doesn't stain
- Non-acid
- Self-cleaning

For soldering all stainless steel and chrome, including 300-400 Series, with ordinary soft solders. Requires no pre-cleaning. Acid-free formulation will not pit metals, leaves no stains. No buckling on even light gauge work. In liquid or paste form.

Write for sample, or engineering help on any fluxing problem.

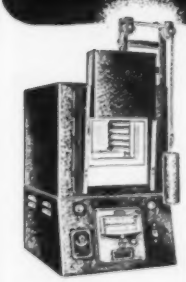
LA-CO BRAND

LAKE Chemical Co.
3079 W. Carroll Ave.,
Chicago 12, Ill.

LIST NO. 202 ON INFO-COUPON PAGE 171

HUPPERT ELECTRIC FURNACES AND OVENS

for Laboratory and Plant



BENCH MODELS

- Range: 300°F. to 2000°F.
- High temperature, heavy-duty Kanthal elements
- Multi-insulation
- Counter-weighted, tight-sealing door
- Operational pilot light
- Shipped ready to operate

Model No.	Inside Dimensions Wide	High	Deep	KW	Prices 220 Volt Single Phase With Huppert Input Controller	With Electronic Prop. Controller
869	8"	6"	9"	4	$296.00	$480.00
11*	8"	6"	12"	4	306.00	518.00
12*	8"	8"	12"	6	382.00	590.00
12A*	8"	8"	18"	9	490.00	698.00

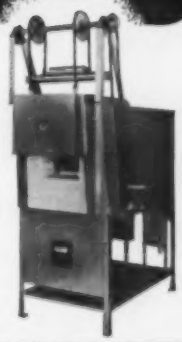
*For 2300°F. add $95.00 to No. 11 and No. 12, and $105.00 to No. 12A. No. 12A can be furnished for 3 phase at no additional cost. For floor model add $52.00 to above prices. No. 869 standardly supplied for 2200°F.

FLOOR MODELS

28 Standard Sizes

- Continuous operation to 1850°F.—intermittent to 1950°F.—for 2300°F. on special order.
- Complete with automatic electronic controller.
- Tight-sealing, wedge-type door.
- Multi-insulation for maximum efficiency.

Shipped Ready to Operate
Model No. 16 Illustrated $1050.00



Also Special Models for Specific Requirements. Special KR-Supers to 3100° F.

K. H. HUPPERT CO.
Manufacturers of Electric Furnaces and Ovens
For A Quarter Century
6844 Cottage Grove Ave., Chicago 37, Illinois

Request new catalog on furnaces, ovens, data, prices.

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SHUSTER MACHINES straighten and cut wire faster better less cost

* Send for free value analysis forms on your present wire requirements . . . Save up to 40% with a new SHUSTER!

* Send for free wall-size wire chart from 41 gauge to 7/0.

* There is a SHUSTER available to straighten, or straighten and cut, wire from .020" to 11/16".

* Check your interests, clip ad, attach to your letterhead and mail to us!

METTLER MACHINE TOOL INC.

155-159 Adeline St.
NEW HAVEN, CONN.

FIRST in wire straightening

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SPECIAL SERVICE ON *HIGH SPEED* STEEL FORGINGS

FAST NATION-WIDE SERVICE ...YOUR STEEL OR OURS

Complete Source For Forged Products Up To 4000#
Rings, discs, spindles, bars or special shapes to your specifications.

28 Years Of Specialized Experience
In production of high speed tool and alloy steel flat die forgings.

Ample Stocks Of Steel Always On Hand

Expert High Speed Steel Blacksmiths

Call or write for free cost quotation on your forging requirements

Smith-Armstrong FORGE, INC.

1209 MARQUETTE ROAD • HENDERSON 1-0320 • CLEVELAND, OHIO

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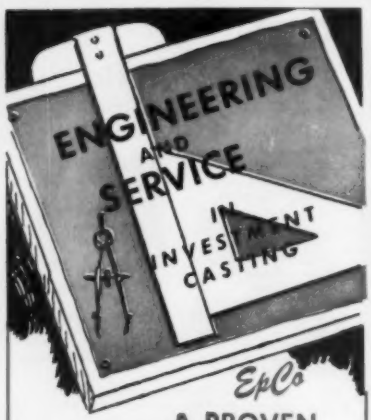
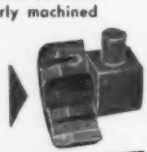


A PROVEN DEPENDABLE SOURCE

FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.



ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

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Are You Making the Best Use of YOUR Free Time?

MOVE AHEAD THE MODERN WAY

with MEI Home Study Courses in steelmaking, electroplating, foundry, welding, heat treating, nuclear power, nonferrous, and other important fields of metallurgy.

For full information write to:

Metals Engineering Institute
7301 Euclid Ave., Dept. PB49
Cleveland 3, Ohio

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GET A BID FROM

HOOVER

SPECIALISTS IN THE FIELD OF

Die Castings

SINCE 1922

Aluminum and Zinc

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

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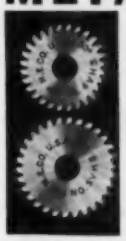
MARTINDALE
METAL SAWS



for fast, precision sawing, slotting, mica undercutting

•

HIGH SPEED STEEL OR TUNGSTEN CARBIDE

Milled, hardened and ground by skilled, experienced craftsmen to exacting specifications. Available in ¾" to 4" O.D., complete range of thicknesses and tooth designs, "U" slot or "V" cutters. Get finest saw blade performance—lowest operating cost.

Send for NEW CATALOG and prices on these and other maintenance, safety and production products.

MARTINDALE ELECTRIC CO.
1372 Hird Avenue Cleveland 7, Ohio

LIST NO. 216 ON INFO-COUPON PAGE 171

ECONOMY and PRECISION in POWDERED METAL PARTS by NORWALK

QUALITY CONTROL from blueprint to finished machine part. Specified strengths and tolerances are maintained from the first part to the millionth.

ECONOMY. Mass production brings the unit cost down for important savings.

SERVICE. Whether delivery requirements are routine or "emergency," we have the flexibility to meet your schedules.

DESIGN. Our Design Engineers employ powdered metallurgy at its maximum potential: to produce precision parts that do the job . . . with important economies in fabrication.

Submit your metal parts problems to us for study and suggestions *without obligation.*

FREE

Write for information folder, "Converting Powdered Metal into Machine Parts".

NORWALK POWDERED METALS, INC.
6 Muller Park, Norwalk, Conn.

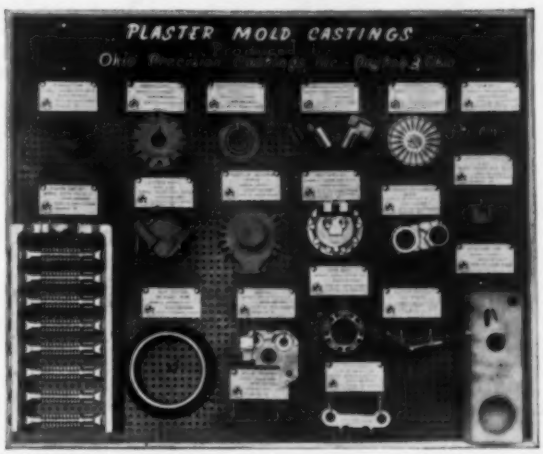
LIST NO. 224 ON INFO-COUPON PAGE 171

A BIG job—for SMALL parts

Every one of these OPC castings represents time and money saved by a manufacturer. You, too, can save time and money by having OPC produce your small parts to the most exacting tolerances, whether you need just a few for experimental purposes or thousands for a production run. Our illustrated brochure shows how and why.

OHIO PRECISION CASTINGS, INC.
Box 55, Sta. A
DAYTON 3, OHIO

Plaster Mold Castings
BRASS • BRONZE • ALUMINUM
BERYLLIUM COPPER



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THE Look of Quality IS IMPORTANT

. . . because this aluminum part, produced by G.E.I., will be viewed by discriminating eyes. It's a thermostat housing for air conditioning controls manufactured by White-Rogers Co., of St. Louis, Mo., for installation in fine homes, exclusive clubs, hotels, restaurants and other such establishments. G.E.I. extrudes this part, cuts to size, blanks and drills, then painstakingly hand polishes, chemically bright dips and gold anodizes it . . . proving once again aluminum can be richly beautiful. The unblemished, soft gold finish of this part is truly attractive. If you have a need for aluminum with emphasis on quality appearance, let a G.E.I. representative tell you why G.E.I. can fill the bill better for less.

GENERAL EXTRUSIONS, INC.
4040 LAKE PARK RD., YOUNGSTOWN, OHIO
Mill Representatives at St. Louis, Detroit, Pittsburgh, Cincinnati, and Chattanooga
Consult your classified phone book under Aluminum Products

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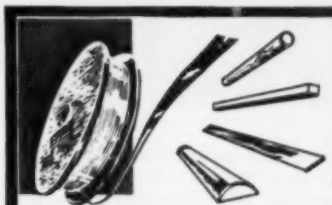

ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LFA **LITTLE FALLS ALLOYS**
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

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HIGH VACUUM

for

laboratory or production . . .

THIS HIGH VACUUM PORTABLE PUMPING STATION

. . . is unequalled in quality and performance — and unmatched in price!

HIGH VACUUM EQUIPMENT CORPORATION

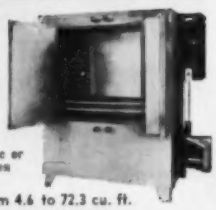
HINGHAM, MASSACHUSETTS

LIST NO. 223 ON INFO-COUPON PAGE 171

UNIFORM HEAT

throughout the work space

30 STANDARD CABINET MODELS



Model HB Electric or Gas Cabinet Oven

- Work space from 4.6 to 72.3 cu. ft.
- Temp. ranges from 100 to 1250° F.
- Electronic combustion devices for gas models
- Indicating control instrument
- Factory tested

Other ovens from $110.50 up; laboratory, bench, walk-in and custom built models.

Write for details

Specialists in Heat Process Equipment

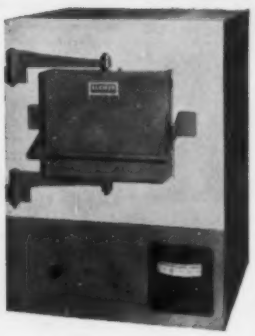
GRIEVE-HENDRY CO. Inc.

1389 W. Carroll Ave. Chicago 7, Ill.

LIST NO. 27 ON INFO-COUPON PAGE 171

HIGH TEMPERATURE 3,000° F.

MODEL 6055E



The Lucifer 6055 Series is available in six standard box or tube-type models.

This series incorporates elements (up to 3,000°F.) that do not require protective atmosphere . . . and element resistance does not change with use. All Lucifer 6055 furnaces feature low initial cost and low maintenance cost . . . each furnace is a complete unit including automatic controller and element transformer.

Our design department will create a furnace to solve your specific heat treating problem. For information, engineering advice or free brochure . . . write, wire or call

LUCIFER FURNACES, INC.

Neshaminy 7, Pennsylvania

Diamond 3-0411

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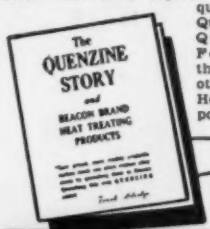
FREE

the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



KELCO

ALDRIDGE INDUSTRIAL OILS, Inc.

3401 W. 140th St., Cleveland 11, Ohio

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See you in Chicago,

November 1 to 6, 1959

at the

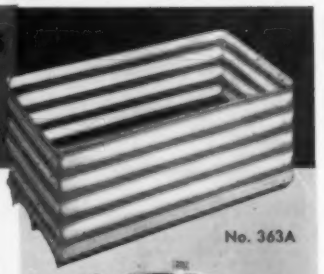
National Metal Congress and Exposition

International Auditorium

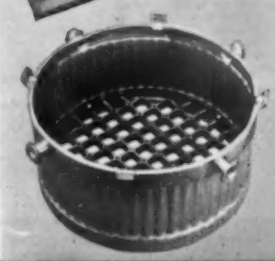
√BASKETS √RETORTS √CARBURIZING BOXES √MUFFLES OF COR-WAL® CONSTRUCTION ARE CUTTING HEAT TREATING COSTS EVERYWHERE!

No. 358

Cor-Wal construction developed by Stanwood engineers has proved its merit in many heat treating departments and commercial heat treating shops. The heat resistant, corrugated rolled alloy metal used in Cor-Wal construction has better loading carrying properties and provides better resistance to thermal stresses—works with the heat, not against it. Send for Bulletin 358.



No. 363A



STANWOOD CORPORATION

4817 W. CORTLAND ST., CHICAGO 39, ILLINOIS

Representatives in Principal Cities

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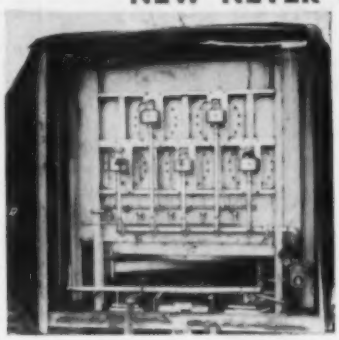
NEW NEVER USED FURNACES
For Sale



Scale Free at 2300°F.

Three (3) SURFACE COMBUSTION Radiant Tube Gas Fired Rotary Hearth Forging Furnaces. 54" hearth diameter, 7½" sq. door opening. Air operated door. Rated capacity 500#/hr. at 2300°F. (Yes, that temperature is correct.) Complete with controls and accessories. These furnaces are NEW! NEVER USED! Present cost of replacement approximately $20,000 each.

Bought—Sold—Serviced

Write for our complete list of furnaces and equipment.

TherMaTek Company

2618 Crane Avenue • Phone VALLEY 2-7632 • Detroit 14, Michigan

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Study of ASM NATIONAL METAL EXPOSITION

analyzes attendance, hours spent at exhibits and at technical sessions.

Check list of materials, equipment and processes visitors want to see at future shows.

American Society for Metals

7301 Euclid Ave.
Cleveland 3, Ohio

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P & K INC.

WE BUY — SELL — LIST

LOCATE QUALITY USED INDUSTRIAL FURNACES

26 YEARS DESIGNING—ERECTING—INSTALLING FURNACES

WANTED—SURPLUS FURNACES.

WE PAY CASH.

WRITE FOR OUR LIST TODAY

PAPESCH & KOLSTAD, INC.

10706 CAPITAL AVENUE
OAK PARK 37, MICHIGAN
P.O. Box 3726 Phone, Lincoln 7-6480

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FOR SALE

MICROMAX CONTROLS AND RECORDERS

40—MODEL C MICROMAX INDICATING CONTROLLERS

20—MODEL S MICROMAX INDICATING RECORDING CONTROLLERS

20—MODEL S MICROMAX POTENTIAL INDICATING RECORDERS
(5 POINT TYPE)

3—ALLEN BILLMYRE 7½ to 15 H.P. GAS COMPRESSORS
COMPLETE WITH SELAS CONTROLLERS

RAYOTUBES, RELAYS AND PANELS—ALL 95% NEW CONDITION

CONTACT

SAMUELS SONS IRON & STEEL CO.

214 Kent Avenue Evergreen 8-4880 Brooklyn, N. Y.

LIST NO. 222 ON INFO-COUPON PAGE 171

Regulate and control electric ovens and furnaces better, accurately, and efficiently with

SORGEL

Saturable Reactors

Any amount of A.C. power from 1 Kva to 3000 Kva, single phase or 3-phase, at any voltage, can be controlled, regulated, and varied in stepless increments, with SORGEL Saturable Reactors.

The control can be a small manually operated hand wheel that can be placed in any desired location, or it can be automatically controlled, regulated and varied by a thermostat or any other instrument or device.

SORGEL reactors are designed to meet your exact requirements. Let us know what your problems and requirements are, and we will submit our recommendations with complete information.

Write for Bulletin 658.

Saturable Reactor with tap changing transformer

●

Also a complete line of dry-type transformers.

All standard and intermediate ratings, ¼ Kva to 10,000 Kva, 120 to 15,000 volts.

●

Sales Engineers in principal cities

Consult the classified section of your telephone directory, under the heading "Transformers," or communicate with our factory.

Sorgel Electric Company

834 W. National Ave., Milwaukee 4, Wis.
Over 40 years of electrical manufacturing development

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FAST • ACCURATE

Low Cost Analysis HIGH TEMPERATURE ALLOYS

Crobaugh Laboratories uses new X-Ray Spectrometer and conventional methods to get accuracy from 1 p.p.m. range to 100%.

COMPLETE METALLURGICAL TESTING SERVICE FOR

- Hydrogen, Oxygen, Nitrogen Analysis
- Elevated Temperature Tensile and Stress Rupture
- Low and High Temperature Impact
- X-Ray, Gamma-Ray Radiography

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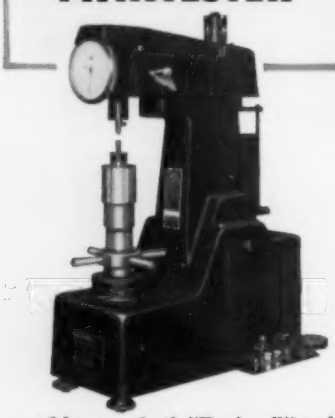
Wilson "Rockwell" TWINTESTER



- Measures both "Rockwell" and "Rockwell" Superficial hardness on B, C, N, T and other scales
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- Large direct-reading dial with one zero set position for all scales
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- Complete line of accessories available

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WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division

ACCO

American Chain & Cable Company, Inc.

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LIST NO. 209 ON INFO-COUPON PAGE 171

GOOD USED EQUIPMENT AT REAL SAVINGS TO YOU!

SACRIFICE BEFORE MOVING!

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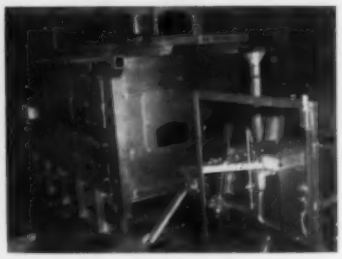

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Capacity: 120 KW to 200 KW
Work Dimension of each: Muffle: Width 14" to 18", Length 8' to 15', Height, 6" to 10".

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INSPECTION SERVICE

A COMPLETE SERVICE PROVIDING DAY TO DAY ULTRASONIC TESTING FOR THE DETECTION OF FLAWS IN MATERIALS.

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LABORATORY TESTING SERVICE

CONDUCTED BY SPERRY ENGINEERS LOCATED THROUGHOUT THE COUNTRY.

Descriptive literature available.

Sperry

Sperry Products, Inc.

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SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

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ASM

SOUTHWESTERN METAL EXPOSITION

May 9 to 13, 1960

Automobile Building
State Fair Park
Dallas, Texas

Floor plans available for third Southwestern exposition selling to industry in Texas, Oklahoma, Louisiana, New Mexico, Colorado, Arizona, California and neighboring states.

For a copy of the floor plans or other information about this important METAL EXPOSITION in a section of the country where industry is growing most rapidly, write . . .

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Buy low-cost Eclipse pressed (not welded) steel pots . . . and replace them on a regular schedule.

1 Lower initial cost
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Guaranteed free from defects. Write:
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Eclipse PRESSED STEEL POTS

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Use Spotcheck
"SPRAY-ON"
Dye Penetrant Inspection

QUICK TEST ENDS VISUAL GUESSWORK!

SPOTCHECK finds cracks, porosity, and leaks you can't see (any defect open to the surface). SPOTCHECK—marks them with a brilliant red warning. Users report speedy, money-saving results. SPOTCHECK is used to inspect metals, carbides, ceramics, plastics, etc. Multi-use SPOTCHECK can simplify your maintenance and in-progress inspections. SPOTCHECK'S complete SK-3 kit is portable; no other equipment needed!

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FLEXIBILITY . . . Use on tools, parts, machinery, etc.
LOWEST COST Dye Penetrant materials—pressure canned or bulk. Why use higher priced substitutes?

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Company _____
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Solve Inspection Sorting Demagnetizing Problems with MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

MULTI-FREQUENCY EQUIPMENT

An eddy current tester with six inspection methods operating simultaneously — for high-speed, non-destructive testing of non-ferrous and non-magnetic tubing, bars and wire from ⅛" to 3" diameter. Detects both surface and sub-surface flaws, and variations in chemical, physical and metallurgical properties at speeds of 200 to 600 ft./min.

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Electronic equipment for inspecting ferro-magnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

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Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

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Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

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Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"

For Details Write:
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42-44 Twelfth St., Long Island City 1, N. Y.

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TENSILKUT

Pat. Pend., U.S., Canada

● Now with TENSILKUT, whatever your testing methods or materials, you can have perfect precision machined physical test specimens in less than two minutes.

● TENSILKUT precision machines all foil, film, sheet and plate metals . . . from .0005" foil to .500" plate. Hard .001 stainless steel foil to soft ½" aluminum, soft plastic film 1 mil in thickness or the abrasive glass laminates to .500" plate, are machined with specimen configurations accurate to ± .0005". Machined edges are completely free of cold working or heat distortion and require no hand finishing.

● TENSILKUT table and floor models are available with motors from ½ to 3½ h.p. Write for free brochure.

SIEBURG INDUSTRIES INCORPORATED
Danbury Industrial Park, Danbury, Connecticut

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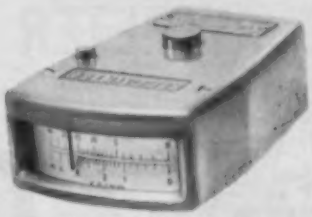
Measures Nonmagnetic Coatings with ±5% ±.0001" accuracy



NEW pocket-size Thickness Gauge

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ONLY
$78.75

FERRO
FERRO CORPORATION
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the GENUINE BRINELL

HARDNESS TESTING MACHINES made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load . . . maximum error plus or minus 2½ kg

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GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3, N. Y.

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NEW IDEA for preheating and stress relieving

ARCOS Heat-O-Coil resistance wire insulated with ceramic beads

• Low cost • Easy to apply • Ideal for field use • Uses standard welding equipment.

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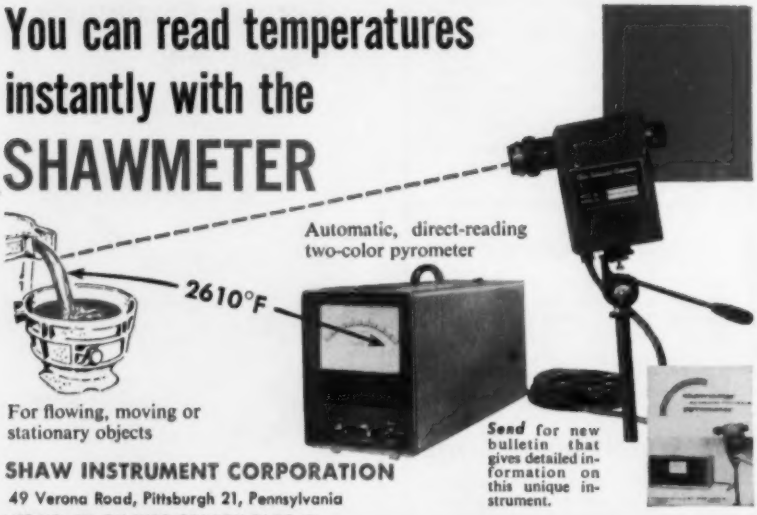

For flowing, moving or stationary objects

Send for new bulletin that gives detailed information on this unique instrument.

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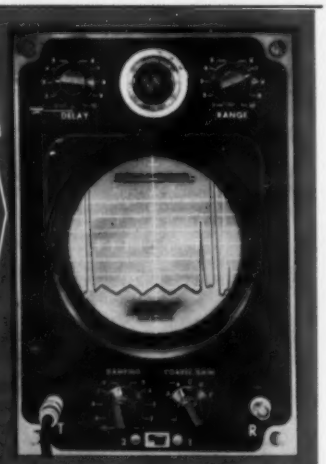
NEW ULTRASONIC FLAW DETECTOR . . . SONORAY MODEL 5



PERFORMANCE, accuracy: 1/10 inch against calibration full gain from 3/4 block at 2.25 mc. resolution: clearly resolves a 3/64" flat 3/4" below surface at 2.25 mc contact. frequency: infinite choice between 500 kc and 10.0 mc.

PORTABILITY: 7½" x 11" x 10½"—35 lbs.

PRICE: complete, ready to use, including transducer — $2,750. Plug-in Flow Meter (optional) — $225.

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Metals for Supersonic Aircraft and Missiles

New ASM Book based on the 1957 Albuquerque Conference on Heat Tolerant Metals for Aerodynamic Applications sponsored by the American Society for Metals and the University of New Mexico.

This is a book for the *designer* and the *metallurgist* who must have an increasingly effective partnership to achieve urgent aircraft and missile goals. It is a book for specialists in—

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This complete documentation of the problems facing metallurgy and design, fabrication and testing, this study of progress to date, should be in your library for study and reference use. It is a new, up-to-the-minute, authoritative book—order now.

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Specialists in Trend-Setting Refrigeration

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NOW . . . AUTOMATION IN METALLOGRAPHY

"PDM"
SAMPLE MOVER . . .
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Write for literature describing this and other modern metallographic specimen preparation apparatus

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Specialists in All Phases of METAL CLEANING EQUIPMENT

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We will be happy to send a sales engineer to help you with any metal cleaning equipment problem. Complete information on request.

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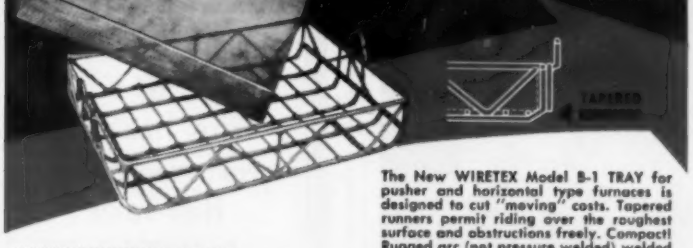
MOVE IT FASTER
...over any surface!



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Call WIRETEX for all your heat treating fixtures, and save.

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INDUSTRIAL 24 Kt GOLD

(aqueous) the world's purest soluble gold, specified and used by many leaders in the Missile, Atomic and Electronic fields.

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The first NEW development in gold electroplating in over 100 years. It produces electroplates both hard and ductile using ONLY ONE addition agent operating at room temperature under POSITIVE and simple control.

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H.G. BRIGHT 23+ Kt GOLD

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A superior rhodium concentrate of high purity offering low stress deposits and tight grain structure.

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Q A

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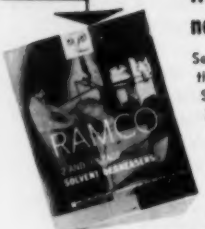

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DIV. OF RANDALL MFG. CO., INC.
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your comprehensive independent mill source of magnesium alloy . .

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RODS ¼" dia. to 6½" dia.
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FOR VICKERS AND KNOOP HARDNESS

STANDARD HARDNESS TESTERS for ROCKWELL and BRINELL TESTS also available.

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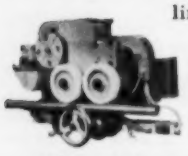
Rubber type, logos and dies . . . imprinting units for rounds or sheets . . . for in-line marking of moving stock.



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3967 FORBES ST. • PITTSBURGH 13, PA.

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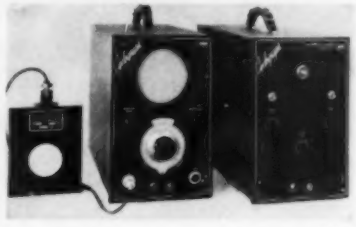
THE CYCLOGRAPH, (Model C)



. . . for unscrambling metal mixups

This instrument permits truly high speed, non-destructive sorting of raw, semi-finished or finished parts by their metallurgical characteristics. With the new Automatic Sorter Unit, speeds up to 300 pieces per minute are possible with the use of suitable feeding equipment. Used by leading industrial firms everywhere.

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• "Non-destructive Testing and Measuring Instruments"

In Canada: Tatnall Measuring and Nuclear Systems Ltd., Toronto

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make hardness tests ANYWHERE WITH THE **NEWAGE TESTER**

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
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Many thousands used by industry and government. Write, wire or call for additional details and prices.

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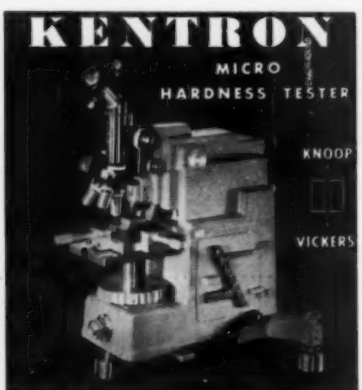
KENTRON MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

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Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

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Eliminates RUST & Fire Hazards Non-Flammable Non-Toxic

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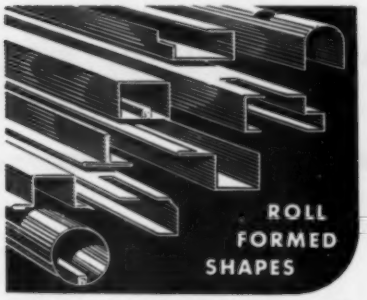

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SOCKET, SET & CAP
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Star Stainless screws have clean—bright—shiny—heads

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ACTOGRAP PEN

Only the ACTOGRAP metal etching pen has all of these features:
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- Short, powerful, continuous arc—will etch hardest metals rapidly
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IDENTIFY PARTS FOR HEAT TREATING!

Markal
PAINTSTIK MARKERS
"M" and "M-10"

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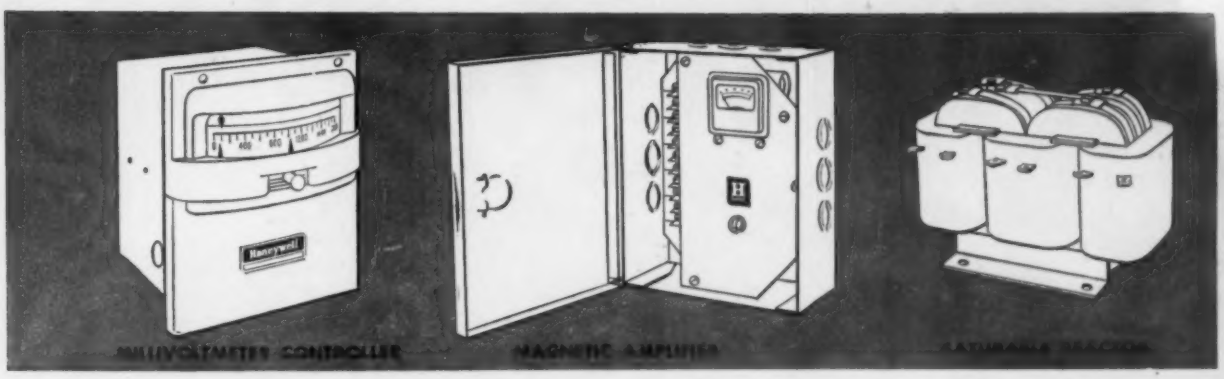

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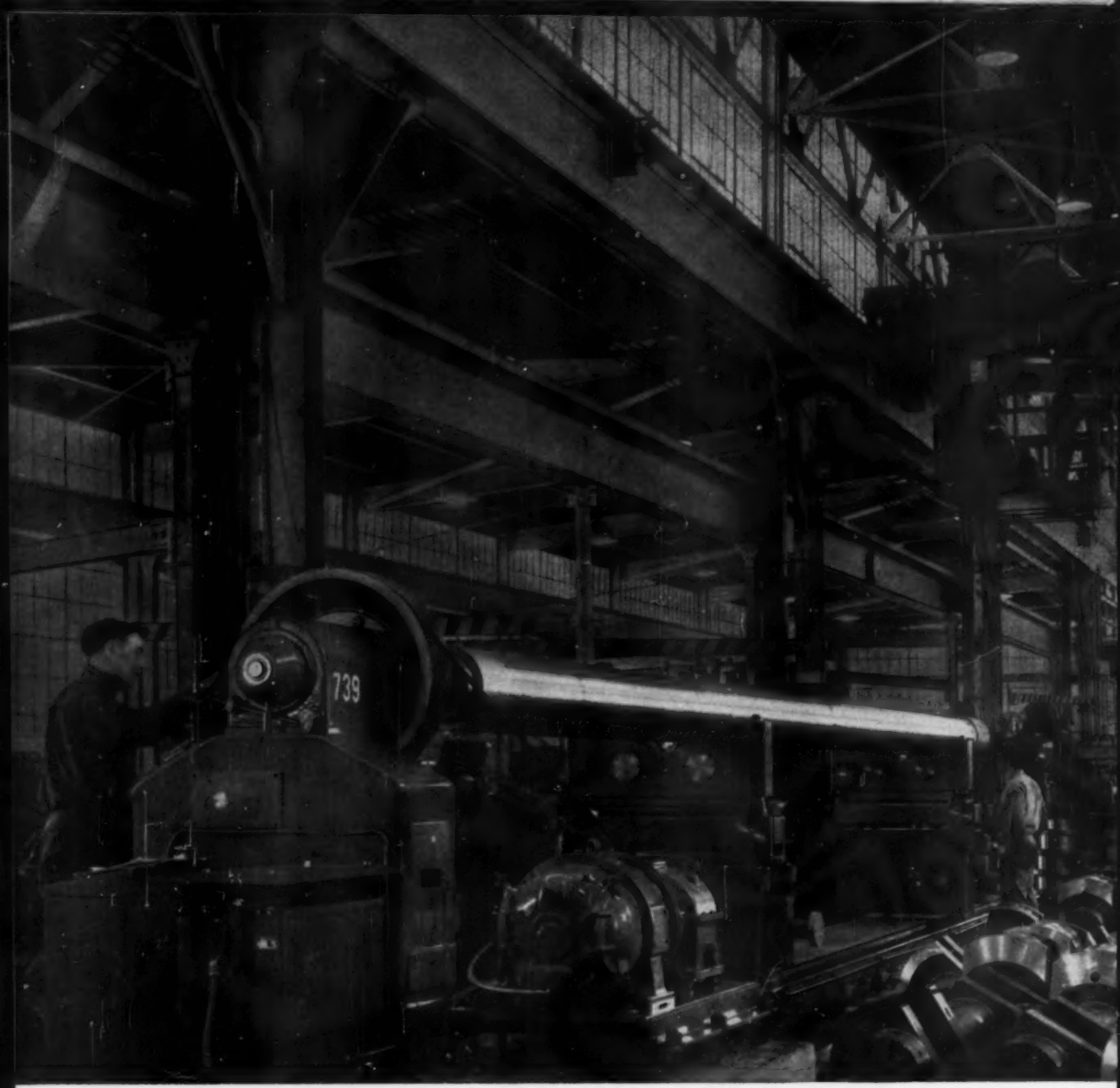

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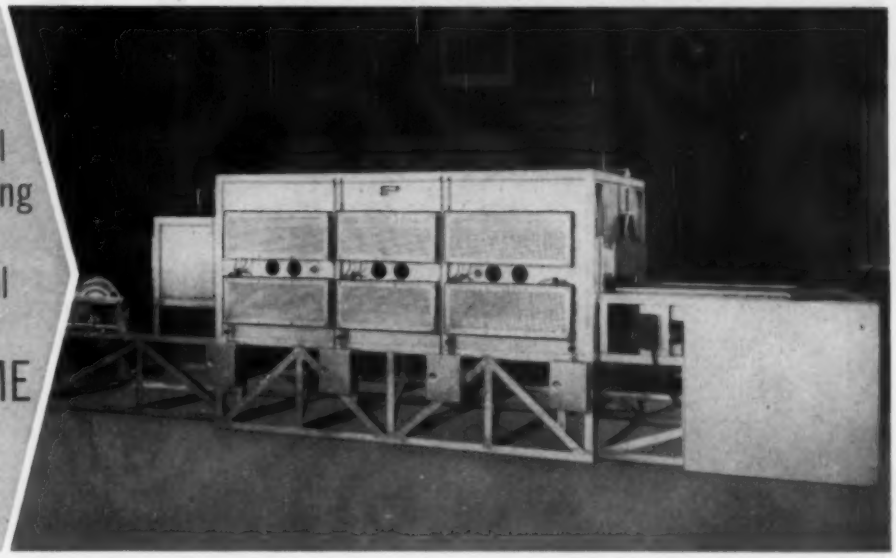

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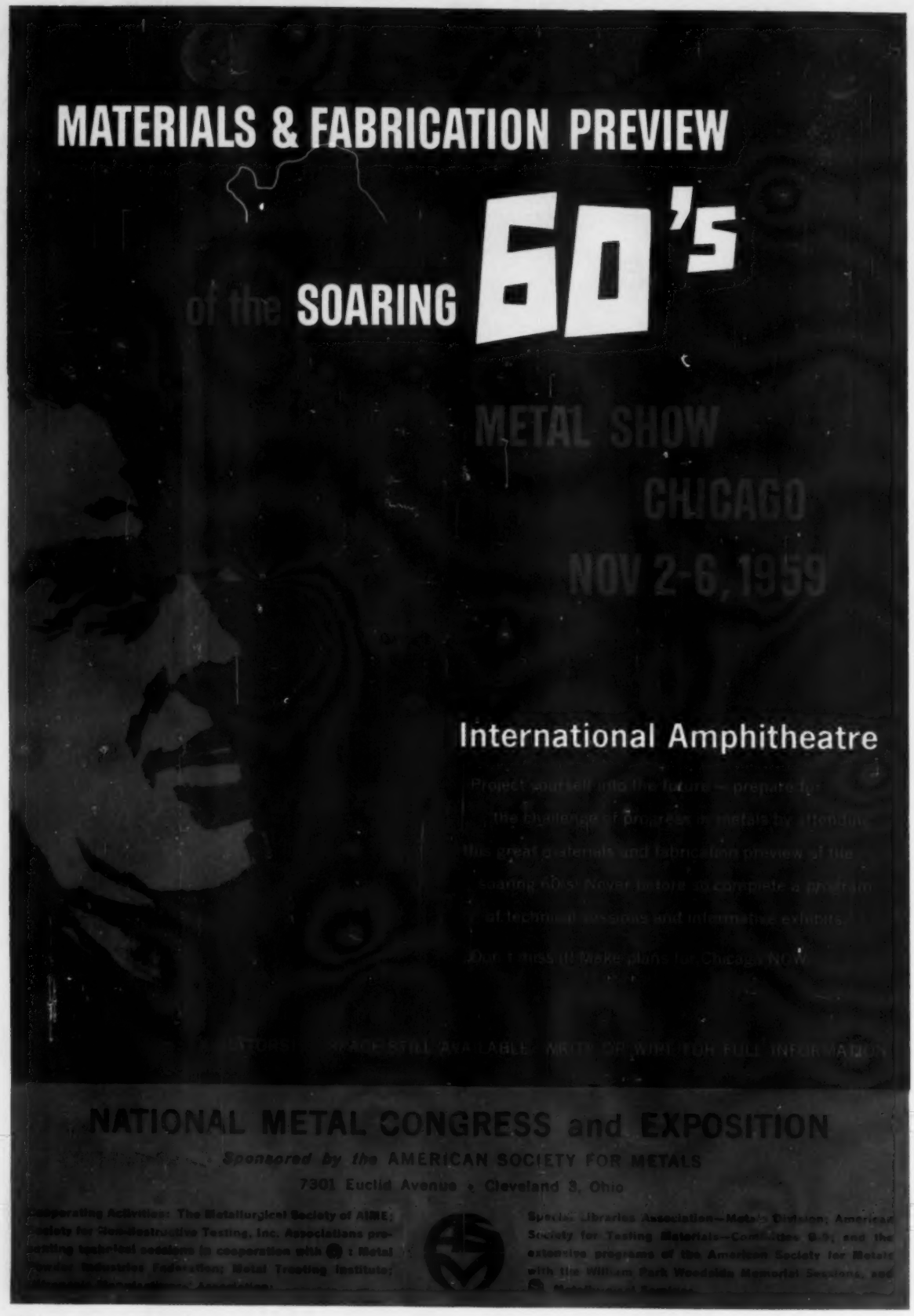
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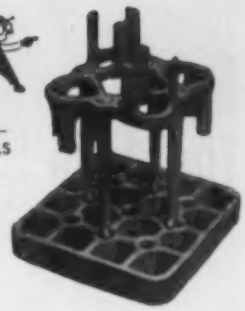

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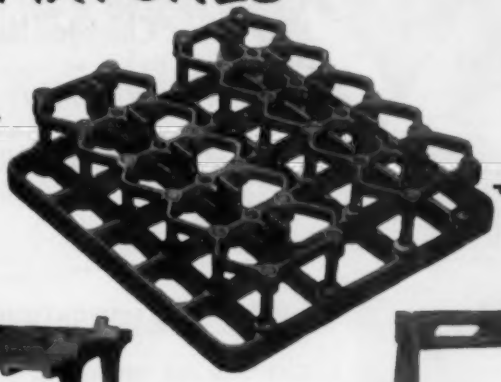

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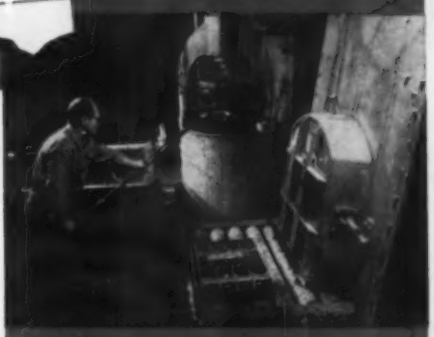

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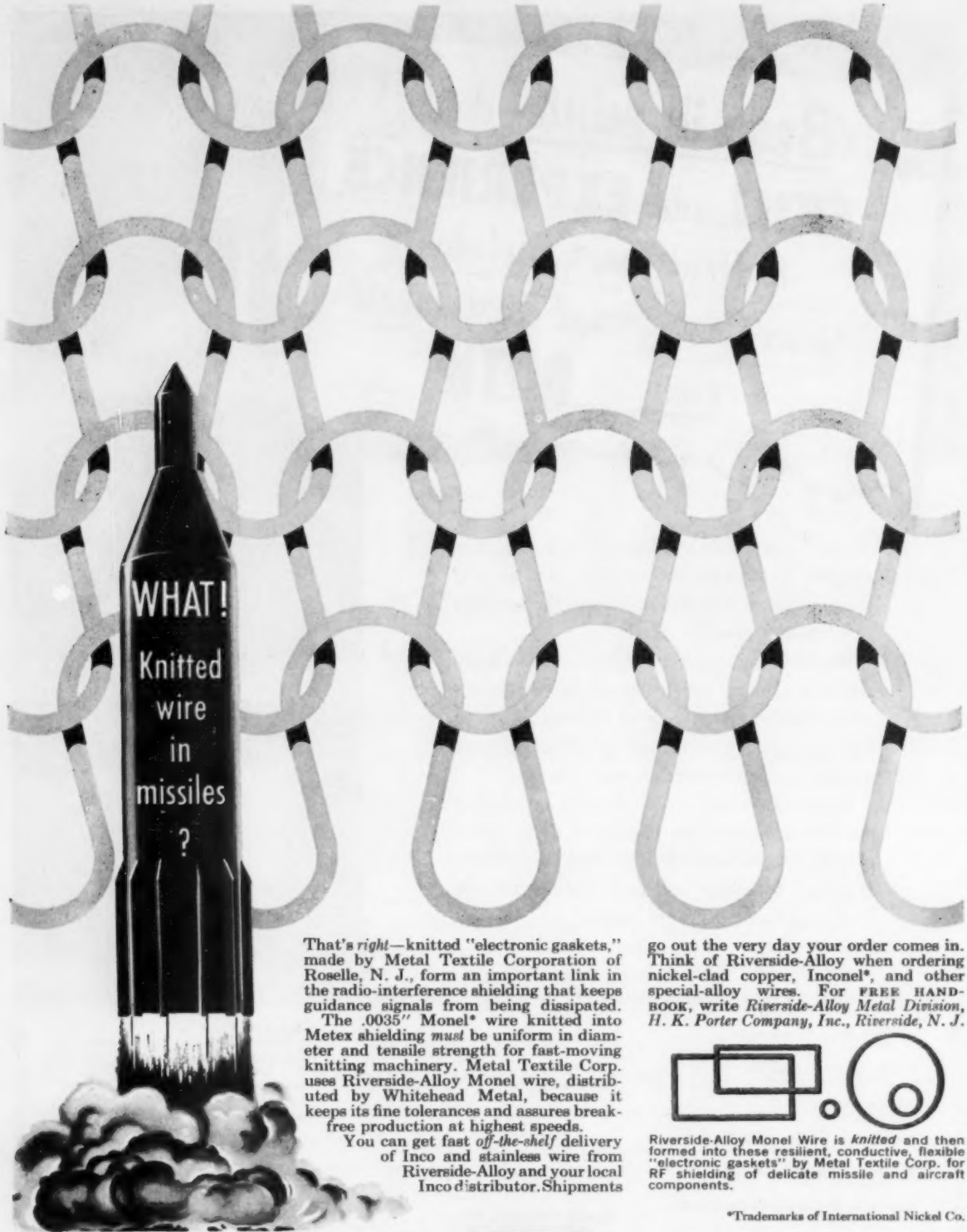

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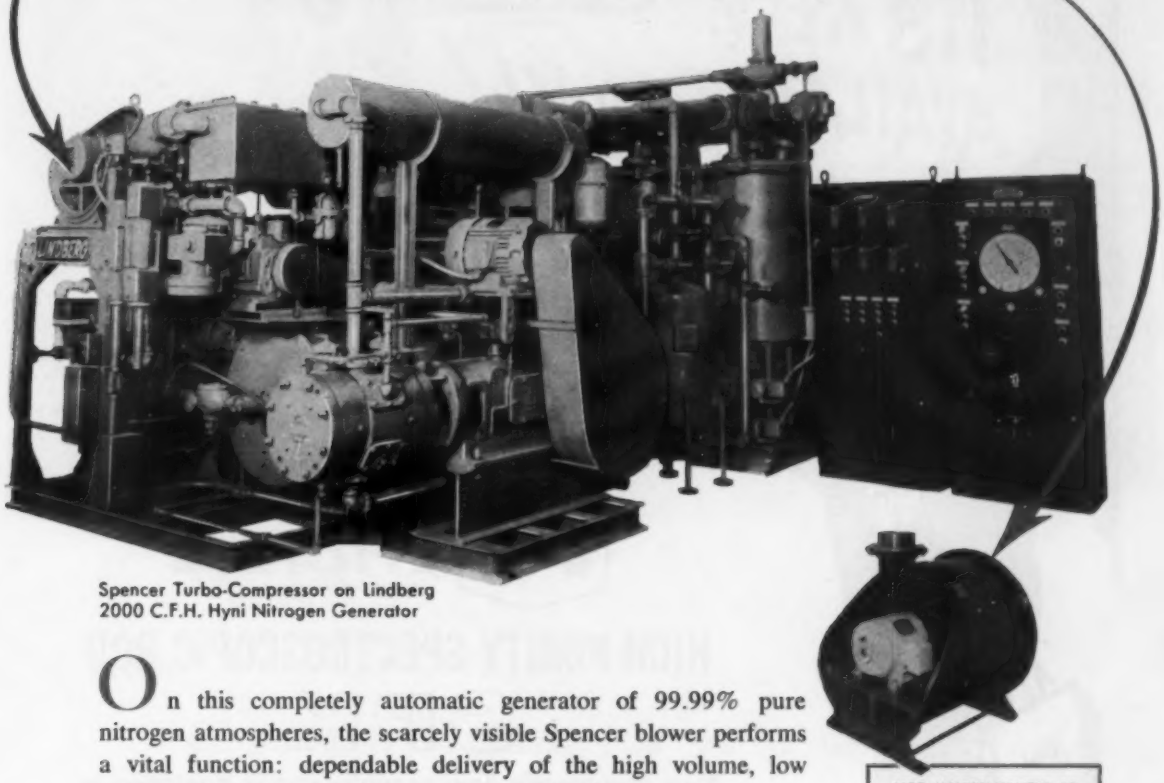

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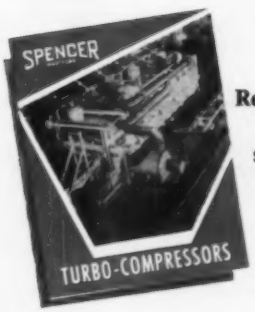

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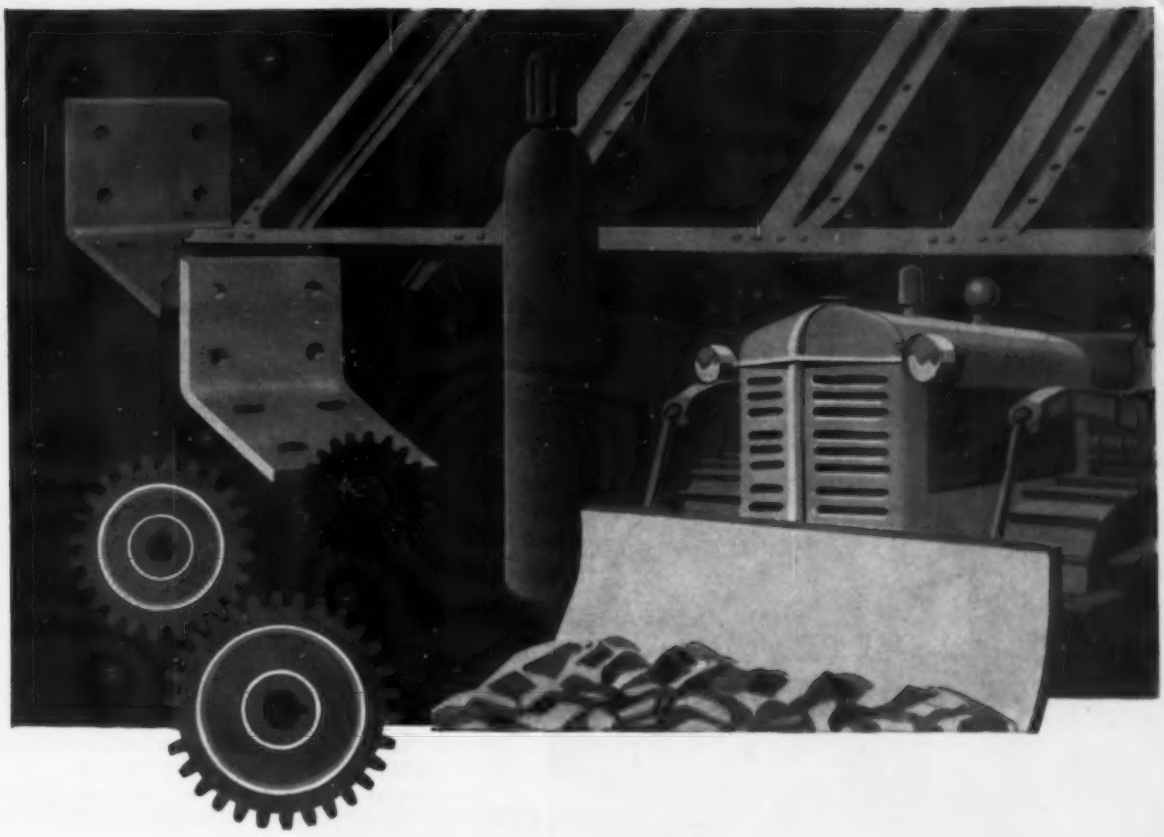

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Section H182-2
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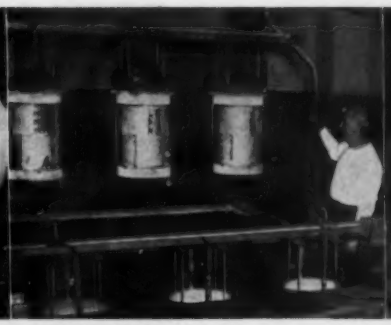

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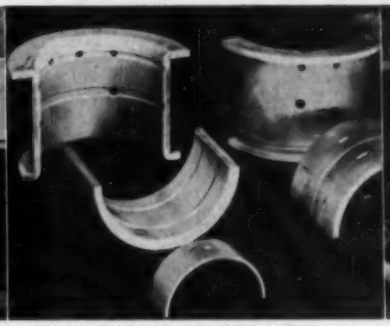

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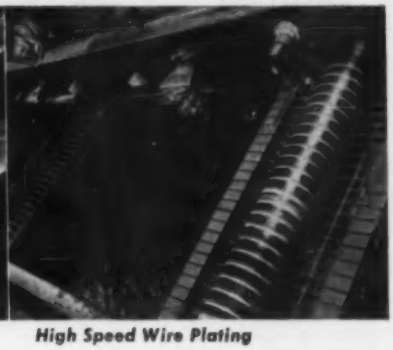

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Sub-Zero	SZH653	6.5	–85° F.	–75° F.	60″	28″	42¾″	47″	15″	16″
Sub-Zero	SZHC657	6.5	–140° F.	–125° F.	60″	28″	42¾″	47″	15″	16″
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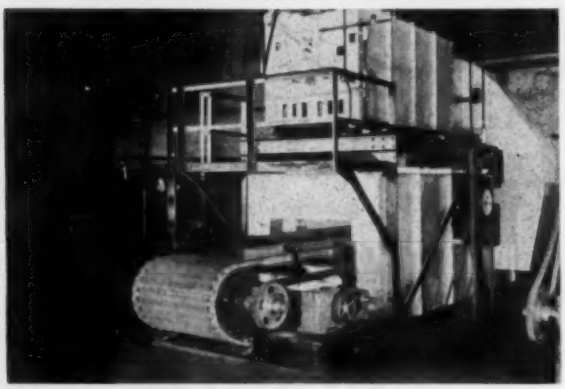

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II

KNOW YOUR ALLOY STEELS . . .

This is the second of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Effects of Elements Used in Alloy Steels

To simplify a rather complex subject, let's outline some of the individual effects of four leading alloying elements used in alloy steels:

Nickel—One of the fundamental alloying elements, nickel provides such properties as deep hardening, improved toughness at low temperatures, low distortion in quenching certain types of tool steels, good resistance to corrosion when used in conjunction with chromium in stainless grades, and ready response to economical methods of heat-treating.

Chromium—This element is used extensively to increase the corrosion-resistance of steel. It also improves the surface resistance to abrasion and wear. It exerts a toughening effect and increases the hardenability.

Molybdenum—This element exerts a strong effect on the hardenability and toughness of steel. It greatly increases short-time and long-time strength at high temperatures.

Vanadium—An element used to refine the grain and enhance the mechanical properties of steel.

A combination of two or more of the above alloying elements usually imparts some of the characteristic properties of each. For example, chromium-nickel grades of steel develop good hardening properties with excellent ductility. And chromium-molybdenum steels develop excellent hardenability with satisfactory ductility and a certain amount of heat-resistance. In other words, the total effect of a combination of alloying elements is usually greater than the sum of their individual effects. This interrelation must be taken into account whenever a change in a specified analysis is evaluated.

Bethlehem metallurgists can be of considerable help to you in selecting the proper alloy steel for any use. These men will gladly give unbiased advice on alloy steel analysis, heat-treatment, machinability, and expected results. Feel free to call upon them at any time.

And please remember, too, that Bethlehem manufactures all AISI standard alloy steels, as well as special-analysis steels and the full range of carbon grades. You can rely upon their quality, always.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

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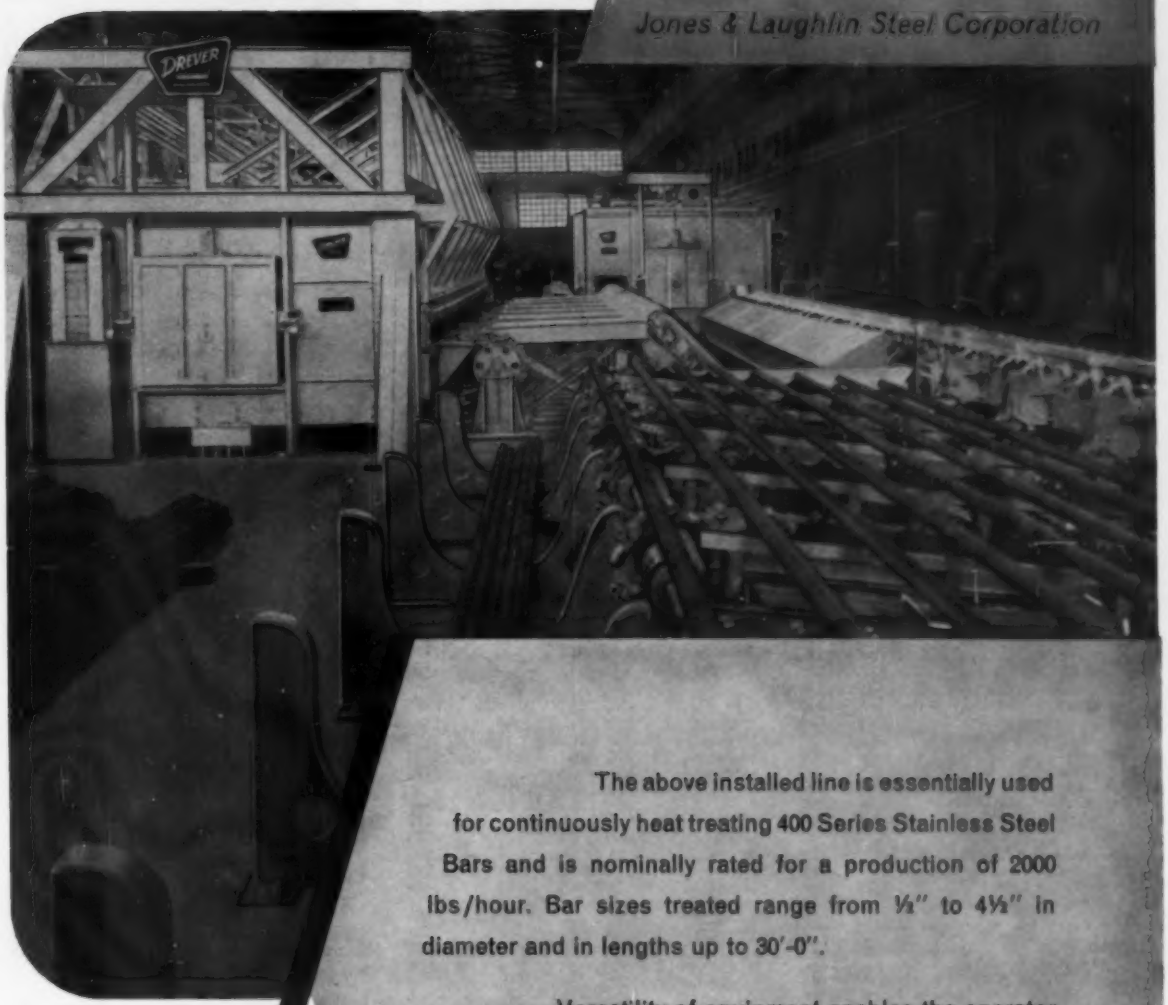
DREVER

Continuous BAR HEATING LINE

at the Detroit Plant of the Stainless and Strip Division of Jones & Laughlin Steel Corporation



The above installed line is essentially used for continuously heat treating 400 Series Stainless Steel Bars and is nominally rated for a production of 2000 lbs/hour. Bar sizes treated range from ½" to 4½" in diameter and in lengths up to 30'-0".

Versatility of equipment enables the operator to automatically change from a normalizing cycle to a heat treat cycle, including quench and draw facilities, without the interruption of the continuous operation.

We welcome your inquiry on your wire, rod, bar, sheet, plate and strip heating problems.

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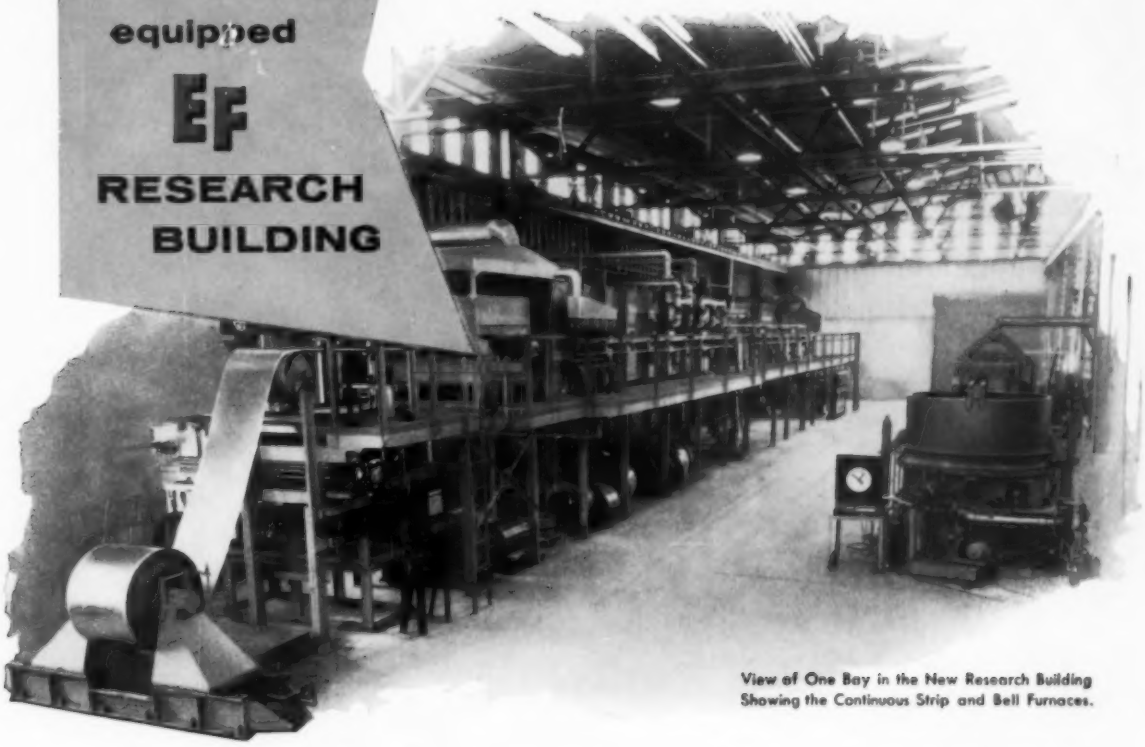

View of One Bay in the New Research Building Showing the Continuous Strip and Bell Furnaces.

to develop and test improved heat treating techniques benefitting all metal producers and fabricators . . .

From the company's earliest beginning research has been traditional at The Electric Furnace Co.

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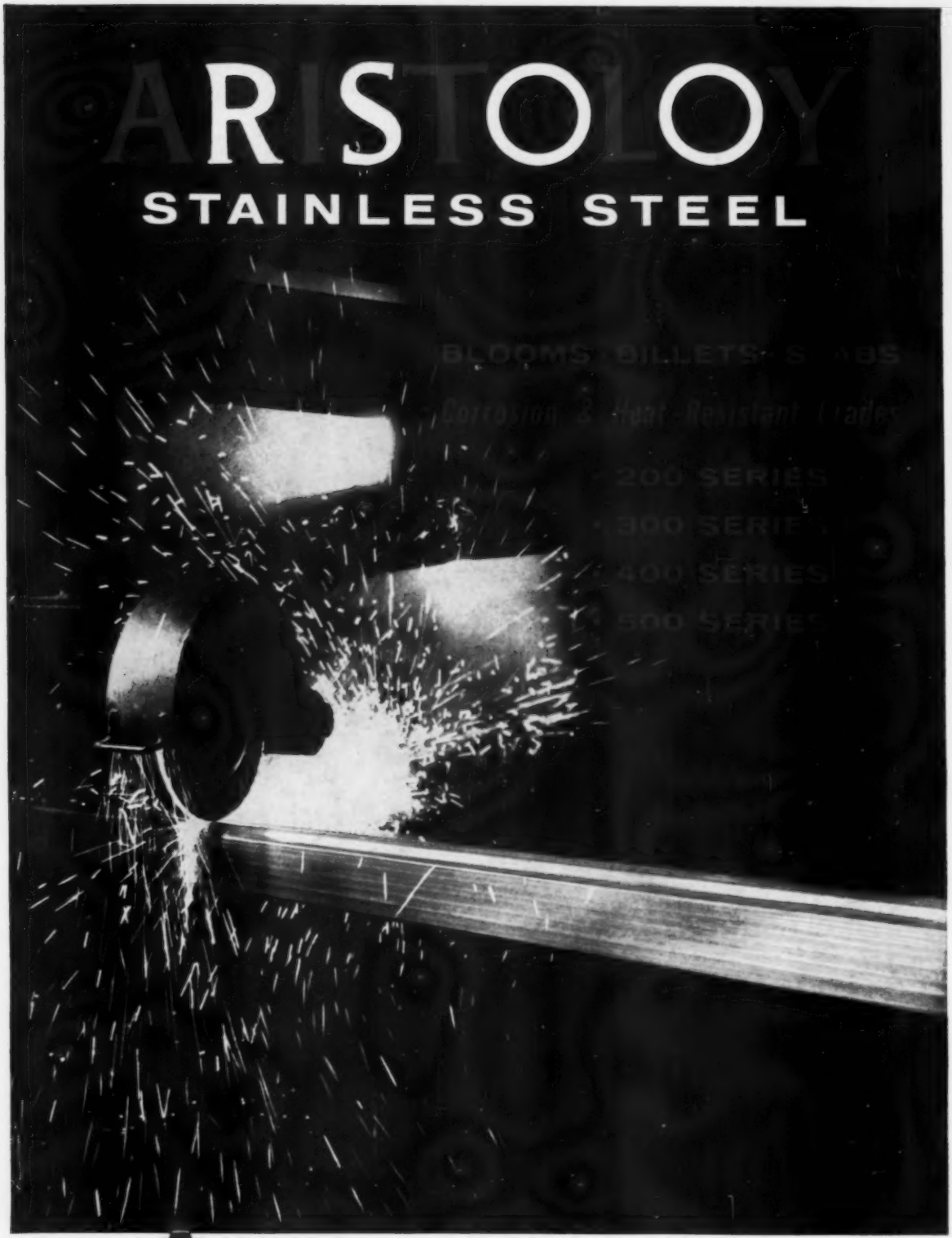

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